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UNIVERSITY OF VIRGINIA

THOMAS LEONARD WATSON, PH. D.
DIRECTOR

Bulletin No. XX

The Clays and Shales of Virginia West of the Blue Ridge

BY

H. RIES AND R. E. SOMERS

CHARLOTTESVILLE
UNIVERSITY OF VIRGINIA
1920

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THOMAS L. WATSON, PH. D.,
Director of the Survey.

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LETTER OF TRANSMITTAL

VIRGINIA GEOLOGICAL SURVEY,
UNIVERSITY OF VIRGINIA,
CHARLOTTESVILLE, DECEMBER, 1920.

*Governor Westmoreland Davis, Chairman, and Members of the State
Geological Commission:*

GENTLEMEN:—I have the honor to transmit to you herewith, and to recommend for publication as Bulletin No. XX of the Virginia Geological Survey Series of Reports, a manuscript and illustrations of a report on "The Clays and Shales of Virginia West of the Blue Ridge," by Professors Ries and Somers.

This is the third one of a series of reports treating of the clay resources of Virginia by major provinces, of which there are three, namely, Coastal Plain (Tidewater), Piedmont Plateau, and Appalachian Mountains. Of these the reports covering the clay resources of the Coastal Plain and Piedmont Plateau provinces have been published. The present report, treating of the clays and shales of the Appalachian Mountains province, completes the survey of the State in this subject.

The region covered by the present report is shown to contain vast clay and shale resources desirable for the manufacture of certain clay products for which there is a large and increasing demand.

Respectfully submitted,

THOMAS L. WATSON,
Director.

THE CLAYS AND SHALES OF VIRGINIA WEST OF THE BLUE RIDGE

By H. RIES AND R. E. SOMERS.

INTRODUCTION.

This report outlines the distribution of the clay and shale-bearing formations within the Appalachian Mountains province of Virginia, together with their possible uses. The field work was carried on by the authors in the summer of 1916, and the territory contiguous to the different lines of transportation searched as thoroughly as time would permit.

Many samples were collected for testing, and it is believed that these will give important clues regarding the possible uses of the clays and shales in the Appalachian Mountains province of the State. Neither time nor funds were available to test out the extent of the deposits in detail, and moreover such work is more properly carried out by private individuals.

The results obtained indicate that the Appalachian Mountains province in Virginia contains a greater variety of plastic materials than either the Piedmont or Coastal Plain provinces, and that it includes clays suitable for common and pressed brick, drain tile, hollow blocks, fire brick, electric porcelain, earthenware, paper, paint, etc.

Some of these deposits are already developed, but many are still untouched, and should become an important resource to the State in the future.

PHYSIOGRAPHIC PROVINCES OF VIRGINIA.

The State of Virginia, considered with reference to its surface features, can be divided into three major provinces: (1) An eastern plain region known as the Coastal Plain or Tidewater province, (2) a central or plateau region known as the Piedmont Plateau, and (3) a western or mountain region known as the Appalachian Mountains province.

TRANSPORTATION ROUTES.

Since the maintenance of a successful clay-working industry depends not only on the proper amount and quality of the clay, but also on facilities for bringing in supplies and shipment of the product, attention may be called to the railroads traversing the territory covered by this report.

The Norfolk and Western Railway traverses the Great Valley from north to south, entering the State above Winchester and leaving it at Bristol, while the Baltimore and Ohio Railway also follows the Valley from the

northern boundary of the State to Lexington. A part of the northern Valley region is also traversed by the Southern Railway from Front Royal southward to Harrisonburg. The main line of the Norfolk and Western Railway, extending from Norfolk, Virginia, to Columbus, Ohio, crosses the Mountains province in a general westerly direction from Roanoke to Bluefield, West Virginia.

The Chesapeake and Ohio Railway also crosses the Mountains province, passing through Basic City, Staunton, Clifton Forge, and Covington, with a branch extending southward from Eagle Rock to New Castle. The Clinch Valley division of the Norfolk and Western, extending from Bluefield, West Virginia, to Appalachia, follows several of the shale areas mentioned in the report, while the Louisville and Nashville from Appalachia to Cumberland Gap reaches additional ones. In the southwestern part of the State the Virginia and Southwestern from Bristol to Big Stone Gap also reaches several shale areas.

In addition to the more important lines mentioned above there are several shorter ones shown on the map, Plate I. The territory is therefore well supplied with transportation facilities.

The clay resources of the first two provinces—Coastal Plain and Piedmont Plateau—have been treated in earlier bulletins of the Virginia Geological Survey.^a

The present report deals with the clay resources of the western or Appalachian Mountains province which is divided into three well-marked physiographic belts, extending across the State from northeast to southwest. Named in order from east to west they are: (1) The Blue Ridge Mountains, (2) the Great Valley, and (3) the Alleghany Ridges.

GEOLOGIC FORMATIONS OF THE APPALACHIAN MOUNTAINS PROVINCE.

The Blue Ridge is composed largely of pre-Cambrian rocks, consisting in part of different igneous rocks, and in part of sandstones and shales of Cambrian age, which are exposed along the western slope, and in places on the eastern slope.^b

^a Ries, H., The clay deposits of the Virginia Coastal Plain: Geol. Survey of Virginia, Bull. 2, 1906, 184 pages.

Ries, H., and Somers, R. E., The clays of the Piedmont province, Virginia: Va. Geol. Survey, Bull. XIII, 1917, 86 pages.

^b For a fuller description of the geology of the Blue Ridge Mountains in Virginia see other publications of the Va. Geol. Survey, especially Bull. XVII, 1919, 166 pages.

Sections across the Blue Ridge can be seen along the James and Roanoke rivers which flow eastward through the Blue Ridge, and along New River, which, heading in North Carolina, crosses in a westerly direction.

On the western slope of the Blue Ridge outcrops of quartzite are prominent on the upper slopes, but the lower slopes, underlain by Cambrian shales, show few outcrops because the bedrock is covered by talus material and alluvial deposits.

In the mountains proper no commercially valuable clays have been found, but on the western slopes of the Blue Ridge within the Great Valley some excellent ones occur.

The Great Valley region is underlain throughout by Paleozoic sediments which range from Cambrian to Carboniferous in age, the chief rock types being limestones, sandstones, and shales of which the first-named predominate.

The geologic section is not the same throughout the Great Valley, because every formational unit is not continuous from one end of the province to the other. Hence four different generalized geological sections have been adopted for the northern, central, and southwestern portions of the Valley region.^a

Moreover the simple horizontal arrangement of alternating soft and hard beds, representing the conditions prevailing at the time of deposition, has been greatly complicated by later folding and faulting of the formations. The rocks have been subsequently subjected to considerable weathering and erosion, which have affected the different beds unequally, the less resistant limestones and shales being more easily weathered and eroded than the more resistant sandstones. At the present time the formations are exposed in long narrow belts, the widths of which depend on the thickness of the formation and the angle of dip.

In the Alleghany Mountain region the rocks which range from Cambrian to Pennsylvanian in age are, to a large extent, hard sandstones and gritty shales, with a few limestones.

In addition to the Paleozoic formations of the Appalachian Mountains province, ranging from Cambrian to Pennsylvanian in age, there are also unconsolidated sediments of Recent age which cover limited areas. These are mostly deposits of the flood-plain type, and include clay, sand, and gravel. The clay-bearing ones are of limited importance, and such occurrences are practically restricted to the Great Valley region.

^a Watson, Thomas L., *Mineral Resources of Virginia*, 1907, 618 pages.
Bassler, Ray S., *the cement resources of Virginia west of the Blue Ridge*, Va. Geol. Survey, Bull. II-A, 1909, 309 pages.

IMPORTANCE OF APPALACHIAN MOUNTAINS PROVINCE FORMATIONS AS A SOURCE OF SUPPLY OF CLAYS.

The clays occurring in the Appalachian Mountains province may be of two types: (1) Sedimentary or transported clays, and (2) residual clays.

SEDIMENTARY CLAYS.

These are represented by two subtypes, namely: (a) Surface clays of Recent age, and (b) shales of Paleozoic age.

Surface clays.—These are distributed in scattered areas, notably within the Great Valley province where flat tracts bordering some of the streams are underlain by deposits of clay of the flood-plain type. As a rule they are inclined to be somewhat sandy, although occasionally they may be very fine-grained and highly plastic, as in the case of the deposit near Lipscomb, Augusta County. Their chief use is for making brick and sometimes drain tile. They are worked at Basic, Augusta County; Covington, Alleghany County; and Roanoke and Salem, Roanoke County. In no case are the deposits very extensive, and, like most flood-plain clays, they may show horizontal and vertical variation changing from clay to sand or gravel, and vice versa. Their depth may be as limited as their horizontal extent.

Shales.—These represent the sedimentary clays in the bedrock formations, and consequently are usually much more extensive than the surface clays of Recent age. They range from Cambrian to Pennsylvanian in age, and vary considerably in their physical characters, but their properties do not stand in any direct relation to their geologic age. Thus we find them ranging from hard gritty shales like the Cambrian ones east of Basic (Field No. 21), or those along the Chesapeake and Ohio Railroad east of Clifton Forge (Field No. 42), to soft, often smooth ones like those at Rose Hill, Lee County (Field No. 102). The hard gritty ones show little or no plasticity even when ground comparatively fine, nor do they weather easily to a plastic mass, while the softer ones grind more easily and form a readily moldable mixture when worked up with water. Between these two there is every gradation.

Some of the fresh shales are highly carbonaceous, like the Devonian shales between Longdale, Alleghany County, and Goshen, Rockbridge County, and this alone would interfere somewhat with their use even if they were otherwise satisfactory.

Concretions are also an undesirable constituent of shales, but few of the Virginia shales contain them. A most noteworthy example of their presence

is to be seen in the shales near Low Moor, Alleghany County (Plate IX, B), in which the concretions are so abundant that at times they form continuous bands. The shales near Richlands may also contain them, but the small ones are usually ground up with the shales, while the larger ones are thrown out in quarrying.

While shale formations are abundant in the Valley and Alleghany Mountains subprovinces, not all of them are of the proper quality when fresh to be of use in the manufacture of clay products. There are quite a number of localities, however, where satisfactory shales occur. Among these may be mentioned Richlands, Tazewell County; Rose Hill, Lee County; Glasgow, Rockbridge County; North Mountain, Augusta County; Walton, Pulaski County; Castlewood, Russell County; Moccasin Gap, Scott County; Tip Top, Tazewell County, etc.

Some shale formations contain interbedded sandstones. If the sandstone layers are not abundant they can be thrown out in quarrying, but if too numerous it may necessitate abandonment of the deposit.

Carbonate of lime is not an uncommon constituent of some shales. It occurs in the shales in several forms, (1) as limestone layers, (2) as concretions, and (3) in a finely divided condition.

The limestone layers can be rejected in quarrying if not too abundant. The concretions are rarely large and are hard to separate, so if the shale is used they must be broken up as much as possible by fine grading. Even then any lumps will cause disintegration after burning unless the shale is fired sufficiently hard. Trouble of this sort is encountered with the shale north of Castlewood, Russell County (Field No. 88).

Lime carbonate in a finely divided condition will, if present in sufficient quantity, cause the shale to fire to a buff color, and hence show the physical properties characteristic of calcareous clays.^a There is this additional point to be noted, namely, that lime carbonate is a somewhat easily soluble constituent of rocks, and if the shale is at all weathered the lime may be leached out of the upper part of the deposit as in the case of the shales at Webster, Botetourt County, and Tip Top, Tazewell County, but is still present in the unweathered portion.

It is highly important to determine whether a shale outcrop is fresh or weathered, because a comparatively slight degree of weathering may sometimes produce a considerable difference in the working qualities of the material, without altering much the structure of the rock.

^a Ries, H., *Clays, Occurrence, Properties and Uses*: 1908, p. 86.

This fact is unfortunately sometimes overlooked by persons lacking geological knowledge. The result of erroneous conclusions which may be drawn is obvious. It is not always possible to judge from surface indications how deep the slight weathering referred to may extend, and hence a greater thickness of weathered shale may be assumed than really exists.



Fig. 1.—Section showing relation of fresh to weathered shale. *a*, Weathered shale, *b*, fresh shale.

As an example, there is shown in Fig. 1 a section of shale outcropping for a distance of 100 feet up a hillside. The shale we may assume has been weathered to an average depth of 6 feet. Tests made of it may show it is sufficiently plastic to mold into bricks. So the deduction may be made that there is a workable deposit 100 feet thick. As a matter of fact, however, there is only a 6-foot deposit of suitable material underlying which is the hard, practically non-plastic fresh shale, which may be of little or no value.

Two examples of this may be cited. There is near Staunton a hard, gritty, carbonaceous shale of little value to the clay worker in its fresh condition, but which when completely weathered forms a very plastic red clay. The fresh material alone does not work satisfactorily, and only a limited quantity of it can be mixed with the clay. The supply of good material is, therefore, very limited, and insufficient to supply a plant of any size. Proper testing of the deposit should bring out this fact. A similar condition is found near Leaksville Junction, Pittsylvania County. Here the Triassic shale is covered by a thin veneer of residual clay. A brick plant was established and endeavored to work the shale as well as the clay, but gave up the attempt after a comparatively short time.

It is therefore of the highest importance that the ground should be thoroughly tested to a sufficient depth before any plans are made for starting a plant. The testing can be done either by borings or test pits scattered over

the property. A small amount of weathering causes considerable difference in the working qualities of a shale, without altering it much in appearance.

In connection with the field work carried on by the Virginia Geological Survey, a number of fresh and weathered shale samples were collected for testing, but, in the case of the latter, the Survey did not have the funds to test out the extent of the deposits, and such work must needs be done by private parties.

RESIDUAL CLAYS.

Those found within the area covered by this report are derived from three different kinds of rock, namely, limestones, shales, and sandstones. Each type may be referred to separately.

Limestone residuals.—With few exceptions the residual clay derived from limestones is of ferruginous character and consequently is red burning. Many of the brilliantly-colored clays found in the Great Valley province are simply the weathered products of limestones. In the process of weathering most of the calcareous matter is leached out so that the clay contains little or no lime. Its depth may be very irregular, and there is a sudden change from clay to bedrock. Since the boundary between clay and bedrock is very uneven, pinnacles of limestone project upward into the clay, thus making it difficult often to accurately estimate the yardage of the latter. The physical properties of these limestone residual clays, collected at a number of different localities, are described under the several localities on later pages of this bulletin. Most of them are very plastic and form a good material for brick or tile manufacture, but they vary considerably in their shrinkage and absorption after firing (p. 55).

In rare cases limestone may yield a residual clay of white color and refractory character.

Shale residuals.—Most shales weather to a residual clay, but they do not all break down with equal rapidity. The depth of clay may also be unequal in different deposits, depending on the depth to which they have been thoroughly weathered. Throughout the area under discussion the shales have, in many cases, been extensively weathered, but not always to the same depth. Most of the shale formations yield clays of ferruginous nature, but here and there the original rock contained but little iron oxide, and the product of weathering is white. This type for example is represented by the clay deposit worked on the northwest slope of the Blue Ridge southwest of Cold Spring, Augusta County, by the isolated deposits north of Buena Vista, Rockbridge County, and by white clays near Mountain Falls, Frederick County.

Here and there also in the iron-ore pits, along the northwest base of the Blue Ridge, there are pockets of white residual clay surrounded by iron-stained clays of similar origin. It is probable that within the original rock there were patches of shale containing little or no iron oxide, and that these on weathering yielded the white material.

White residual clays are also found associated with the Oriskany iron ores in places.

Sandstone residuals.—Sandstone consisting entirely of quartz grains will not yield residual clay, but if the parent rock contains much clayey cement or an appreciable quantity of feldspar grains, then the product of weathering will be a clay, although it may be of a sandy character. The best example of a clay of this type in the area covered by this report is that found two miles east of Christiansburg, Montgomery County, and described on page 74.

There is also a possibility that some of the pockets of white clay found in the brown iron-ore pits, previously alluded to, may have been derived from a feldspathic sandstone and not a shale, as the material is occasionally quite sandy.

TESTING OF SAMPLES.

Since it is the physical properties and not the chemical analysis of clays that are of primary importance, these were given special consideration in this report.

Chemical analyses being, as a rule, of little use in determining the value of a clay for the manufacture of burned-clay products, were made only in a few cases. The localities from which samples were collected are indicated by field numbers on the map (Plate I), and these are also given under the detailed descriptions in the text.

Large samples were collected from those localities where a considerable body of clay was in sight, and smaller samples were taken from many other localities where conditions for extensive sampling were not so good, or in those cases where a large sample had already been collected at some other point within the same formation. The large samples were fired at a number of temperatures, while the small ones were fired at only one or two temperatures.

The tests which are made on clays enable us to classify them with respect to their uses for different purposes, since different ceramic products call for different kinds of clays. The physical tests which may be carried out on clays are discussed below.

PLASTICITY.

Plasticity is the property wet clay possesses of forming a pasty mass, which permits molding into any desired shape. There is no satisfactory means of measuring plasticity, although with practice a person can recognize the different degrees of it, and describe it by such terms as poor, fair, and excellent.

The chief cause of plasticity is probably the contained colloidal particles, although organic matter is present in some clays, and texture no doubt also exerts an important influence.

WATER OF PLASTICITY.

It is necessary to add a variable amount of water to different clays to render them plastic. This is known as the water of plasticity. As a rule a highly plastic clay will require more water than one of low plasticity, and even in any one clay the quantity of water is not fixed, but may vary between maximum and minimum limits. In highly plastic clays the limits referred to above are in general more widely separated than in clays of low plasticity. The water of plasticity consists of two parts, namely: (1) Shrinkage water, which is that portion driven off up to the point where shrinkage ceases, and (2) pore water, which is that portion driven off by heating to 110° C. after shrinkage ceases.

Shrinkage water can be determined by the formula:

$$\text{S. W.} = \frac{V_w - V_d}{W_d} \times 100.$$

in which

S. W. = per cent shrinkage water.

V_w = Plastic volume.

V_d = Dry volume.

W_d = Dry weight.

For determining pore water the formula used is:

$$\text{P. W.} = T - \text{S. W.}$$

in which P. W. = per cent pore water.

T = per cent water plasticity.

S. W. = per cent shrinkage water.^a

AIR SHRINKAGE.

During the process of drying the moisture in clay is brought from the interior to the surface, being drawn through the capillary pores, and

^a Formulae suggested by Committee on Standard Tests, Amer. Ceramic Society.

evaporates. As the drying proceeds and the water evaporates, the clay particles move closer together, until they are in contact, when shrinkage ceases. Even then there is still some water left in the spaces between the grains, and, while some of it may evaporate at room temperature, most of it is not driven off until the clay is heated above 100° C.

Highly plastic clays have a higher water of plasticity content; hence have to get rid of more water in drying, and consequently they exhibit a higher air shrinkage.

A high air shrinkage is undesirable because of the tendency to warping and cracking which it induces; consequently such clays cannot be safely used alone, but must be mixed with other materials having a lower air shrinkage. This may be accomplished either by mixing in a clay of lower air shrinkage, or by adding some non-plastic material such as sand, ground flint, or calcined clay. The material used for lowering air shrinkage will depend on the character of the product to be manufactured.

In making common brick sand is sometimes added to the clay, or, where the material is of sedimentary character, different beds in the deposit may have a different air shrinkage, so that a mixture of them gives the desired results. The shrinkage of fire brick and terra cotta clays is often reduced by the addition of calcined clay or ground fire brick. In white ware bodies, the high air shrinkage of a ball clay will be counteracted in part by ground flint.

The determination of drying shrinkage may be either linear or by volume. In the former case the test bricklets after molding have two marks made on them, whose distance apart is carefully measured. After thorough drying in the room and hot air bath the distance between the marks is again measured, and from these two determinations is calculated the per cent drying shrinkage expressed in terms of the original wet length.

If the drying shrinkage is determined in terms of volume, it is necessary to measure the volume of the test piece after molding and drying, and then calculate the per cent volume shrinkage in terms of the dry volume.

The volume shrinkage may be calculated by the formula:

$$V. S. = \frac{V_w - V_d}{V_d} \times 100.$$

in which

V. S. = per cent volume shrinkage.

V_w = Volume wet.

V_d = Volume dry.

The linear shrinkage can be calculated from the per cent volume shrinkage as follows:

$$\text{L. S.} = 1 - \sqrt[3]{1 - \frac{\text{V. S.}}{100}} \times 100.$$

in which L. S. = linear shrinkage.^a

FINENESS.

This test is made for determining the percentage of particles of different degrees of fineness which a clay contains. It is usually carried out only on the higher grades of material, such as white-ware clays, paper clays, and refractory-bond clays.

The larger-sized particles can be separated by means of sieves, but the small ones need to be separated by an elutriation process. In this they are sorted or classified by means of a gently flowing rising current of water. Very plastic clays contain a high percentage of very fine particles which pass through a 200-mesh sieve.

SLAKING.

This test, which is more often carried out on high-grade clays than on low-grade ones, is an indication of the bonding strength of the material, since the stronger clays take a longer time to disintegrate.

It is carried out by thoroughly mixing equal parts of the dry clay and potters flint. This mixture is molded into one-inch cubes, which are dried first at room temperature, and then at 100° C. When cooled these are submerged in water on a screen of four meshes to the inch, and the time noted that it takes the cube to slake through the netting.

STRENGTH OF CLAY.

Clays of high plasticity usually fire to dense bodies of high strength, and such clays generally show a similarly high strength in their unfired condition. This strength of the unfired clay may be ascertained by determining either its tensile strength or its transverse strength.

The tensile strength test is made by molding the clay into briquettes similar to those employed in testing cement. These are thoroughly dried and then pulled apart in a tensile-strength testing machine. Since the briquette when first molded has a cross-section of one square inch, but shrinks in drying, it is necessary to measure the cross-section of the briquette before testing. From this and the strength as broken the tensile strength in pounds per square inch can be calculated.

^a Report Committee Standard Testing, Amer. Ceramic Society.

To test the transverse strength, the clay is formed in bars six inches long and one inch square cross-section. These are thoroughly dried first at room temperature and then in a hot-air bath at 110° C. After cooling the bars are supported on narrow bars 6 inches apart, and pressure applied to the upper surface midway between the supports.

The modulus of rupture is calculated from the following formula:

$$\text{Modulus of rupture} = \frac{3 \times \text{weight in lbs.} \times \text{distance between supports.}}{2 \times \text{width of bar} \times \text{thickness of bar}^2}.$$

The width and thickness of bars are measured before breaking.

Proper drying is essential to obtain the maximum strength of the clay, and it should be dried first about 60° or 70° C., and then at 110° C. It should not be allowed to absorb moisture from the air after drying and before testing.

BONDING TEST.

To determine the bonding power of a clay it is thoroughly mixed with equal parts of standard sand and molded into bars as described under transverse strength. The strength of the clay-sand mixture may be either lower or higher than that of the clay alone as the following figures^a will show:

Modulus of Rupture of Some Ball Clays and Bonding Clays.

	Without sand	With sand
English ball clay.....	376	323
English ball clay.....	366	389
Klingenberg, Germany, A. T. clay.....	345	381
Kentucky ball clay.....	239	234
Kentucky ball clay.....	359	362
Tennessee ball clay.....	187	199
Tennessee ball clay.....	326	228
Tennessee ball clay.....	387	282
Southern Illinois clay.....	338	262
Northern Mississippi clay.....	645	326

A clay of high bonding power is able to carry a considerable quantity of non-plastic material.

COLOR.

The color of a raw clay is not always an index of the color it will show in the fired condition. A ferruginous clay, that is one stained by iron oxide, will usually fire to a red or brown color, although such clays sometimes contain sufficient lime carbonate to make them burn buff.

^a Quoted by Parmalee, *The Resources of Tennessee*, Vol. IX, No. 2, 1919, p. 187.

A white clay often fires to a white color, but may contain sufficient iron oxide (which is not evident in the raw material) to make it fire buff.

A black clay, the color of which is due to organic matter, may fire to a white, buff, or red color, a point often difficult to determine in advance, since the organic material may mask iron impurities otherwise noticeable. Gray clays may fire to different colors.

Since the color of the fired clay is of importance, it should always be noted.

FIRE SHRINKAGE AND VITRIFICATION.

Clays in firing undergo important changes in size and porosity, the two proceeding more or less parallel. As the clay is exposed to a rising temperature it shrinks to a certain point, beyond which it expands. This is accompanied by a decrease in porosity to the point of maximum shrinkage, after which the porosity increases.

The stage through which the porosity increases is known as the over-firing stage, and terminates in fusion, when the material becomes so soft that it is no longer able to hold its shape, and deforms.

Different clays show considerable variation with respect to the above properties. Calcareous clays for example show low fire shrinkage and high porosity up to a certain point, beyond which the shrinkage increases rapidly, and the porosity decreases rapidly up to fusion.

Many refractory bond clays on the other hand retain their condition of minimum porosity through a wide temperature range before beginning to overfire. In other words, they have a long firing range. In firing a clay, therefore, it is important to determine the fire shrinkage and the porosity or absorption at different temperatures.

The linear fire shrinkage can be determined by measuring the same shrinkage marks that were used for determining the drying shrinkage, and is calculated in percentage terms of the freshly molded test piece. It can also be calculated from the volume shrinkage (p. 11).

The porosity can be determined by the following formula:

$$\text{Porosity \%} = \frac{\text{Saturated weight} - \text{dry weight}}{\text{Saturated weight} - \text{suspended weight}} \times 100.$$

The test piece is saturated by submerging for 24 hours in water, and then boiling for one hour. It is then removed from water, excess of water wiped off surface, and weighed. The suspended weight is obtained by weighing the saturated piece suspended in water.

The absorption is determined by weighing the dry test piece, soaking in water for 48 hours, and weighing again. The increase in weight gives the weight of water absorbed, and the percentage of absorption is calculated in terms of the original dry weight.

HARDNESS.

The hardness of a clay after firing is determined by noting whether or not it can be scratched with a knife. Thus it is described as being "steel hard" or "not steel hard."

MINERALS IN THE CLAYS.

Few of the clays and shales in the region covered by this report show any mineral grains of sufficient size to be visible to the naked eye. Those which can be so recognized are usually quartz and mica. The clays associated with the gypsum deposits at North Holston contain grains of this mineral.

A number of the clays and shales were examined under the microscope. The microscopic examination showed that kaolinite, hydromica, and quartz were the most abundant recognizable minerals. In addition to these there were noted zircon, rutile, epidote, biotite, muscovite, plagioclase and tourmaline, which occur in very small amounts. One shale showed considerable calcite, but otherwise this mineral was very scarce in the materials examined.

It cannot be said that any one group of clays differed in any marked way from another group. Quartz was common in most of the samples examined, but was most abundant in the clays of the flood-plain type. Kaolinite was more abundant in the white residual clays of the Cambrian, and in the shales, than in the residual clays derived from the Cambro-Ordovician limestones of the Valley province. In most of the last named, hydromicas were abundant, while in the Cambro-Ordovician shales it was as common as kaolinite.

Not enough work has been done on the mineralogy of impure clays in their raw and fired condition to draw many deductions from the mineral composition of the unfired material. It seems probable, however, that hydromica exerts more influence as a fluxing constituent than kaolinite.

CHEMICAL ANALYSIS.

In judging a clay for the manufacture of clay products, little attention is now paid to chemical analysis, except for special purposes. The reason for this is that a chemical analysis gives but little information regarding the physical properties of the material. Very few chemical analyses were therefore made for this report.

It may be said by way of explanation that high-grade, white-burning clays are made up chiefly of silica, alumina, and chemically combined water, with a low percentage of iron oxide. The more impure clays contain an appreciable total quantity of iron oxide, lime, magnesia, potash, and soda, which tend to lower the fusing point. The red or brown color after firing is due to the content of iron oxide, while buff may be due to a limited amount of this ingredient, or to an excess of lime over iron oxide.

DISTRIBUTION OF CLAYS IN THE APPALACHIAN MOUNTAINS PROVINCE.

Clays and shales are widely distributed in the province covered by this report, and they vary considerably in their quality. Since one clay may be used for several different purposes, it is not practicable to group them according to kinds, but a more satisfactory grouping is by geologic formations, under which the clays and shales are treated in this report.

CAMBRIAN FORMATIONS.

The Cambrian formations of the region covered by this report form a somewhat irregular belt along the east side of the Great Valley province, extending entirely across the State. There are also some scattered areas in the Alleghany Ridges subprovince in the southwestern part of the State, which include the formations known as the Nolichucky shale and the Russell shale.

The shale belt first mentioned has thus far afforded nothing of value to the clay-product manufacturer in its fresh condition, but a slight amount of weathering may make the material workable (as at Glasgow), and when well weathered it yields residual clays that are often of value. These residual clays are usually ferruginous, but at several points the shale has yielded locally important deposits of white residual clay. The latter are represented by a series of white clays found in a belt extending from Lipscomb, Augusta County, to Buena Vista, Rockbridge County. Further south there are residual clays derived from shale in Wytke County, and the yellow and white clays associated with the brown iron-ore deposits.

The Nolichucky shale and the Russell shale, of southwest Virginia, yield plastic materials even when little altered.

WHITE RESIDUAL CLAYS OF MIDDLE WESTERN VIRGINIA.

Along the western side of the Blue Ridge there are a number of exceedingly interesting deposits of white and gray white clay, which have

been developed to a limited extent. The most northerly one of which we have any knowledge, is near Island Ford, but it is as yet undeveloped. A second is known near Lipscomb, Augusta County, and was worked a number of years ago. Another is southeast of Cold Spring, and is being actively worked. One is known close to Lofton, and still another at Pekin northeast of Vesuvius. Others are known near Buena Vista, Rockbridge County, where they have been worked for some time for the manufacture of fire brick. It is probable that additional deposits may occur in the area noted. All of these clays occur in the Cambrian shale belt, and are undoubtedly of residual origin, but in no case has fresh or nearly fresh shale been found in close association with the clay. At Lofton, however, the shale is found outcropping on several sides of the clay area, and the clay is located directly in the line of strike of some of the shales. In view of the fact that the Cambrian shales from which these clays are probably derived are of some extent along the northwestern slopes of the Blue Ridge, a further careful search should be made for additional deposits.

A noteworthy fact is that the several deposits of white clay show a curious divergence in their physical properties, such as plasticity, fire shrinkage, and density of burning. None of the white clays fire white, but to some shade of cream or creamy white.

Descriptions of the several localities follow:

AUGUSTA COUNTY.

Lipscomb.—In the area south of Lipscomb and east of Stuarts Draft there are many reported discoveries of whitish clay, said to have been found in the digging of wells, some of which was reported to have been encountered within 8 feet of the surface, but at other times it was found at greater depth. The clay showed a variable amount of mottling from iron oxide, as well as from sand. Occasionally it is described as being flinty, which means probably that it contained pieces of chert. This fact would suggest its being residual from limestone, which is not impossible since the area in which it lies is mapped as the Shenandoah group of limestones.

It is also entirely conceivable that the limestone might on weathering yield white clay, for while most of the residual clay from the limestone is highly ferruginous, the clayey impurities in some limestones may at times contain very little iron oxide and hence could yield a white residual clay.

The only locality in this area where any systematic attempt was made in earlier years to extract the white clay is about half a mile southwest

of Lipscomb on the J. W. Goode property (Field No. 16*). Here the clay was dug at the close of the Civil War and used for the manufacture of Rockingham ware by the Virginia Porcelain Company. About 1873-1875 the Virginia Porcelain and Terra Cotta Company operated the property, while still later a firm known as the Virginia China Clay and Fire Brick Company made fire bricks and washed clay to be shipped to the potteries.

At the present time there are no exposures of white clay visible, and the old shaft which had been sunk to work the clay was filled with water. Mr. Goode, however, had this cleaned out so that we could make at least a superficial examination. At a depth of 30 feet a drift was turned off from the shaft having a southeast direction, in the face of which was a white clay showing a few iron-oxide stains in the cracks. The clay shows a banded structure consisting of darker-colored (gray) streaks about an eighth of an inch thick, and about half an inch apart. If these streaks represent stratification, then at this particular point the strike is N. 30° E., and the dip 20° SE.

We were informed that, in sinking the shaft, white clay with some organic matter was struck at a depth of 8 feet, and that from this depth to 26 feet white clay with some sandy layers was shown, while below this to 50 feet the clay was mostly white. At the bottom of the shaft a mixture of red, yellow, and blue clay was encountered.

Near this shaft there is an outcrop of clayey limestone, whose weathered surface has a banded appearance much like the banding referred to in the white clay. The limestone strikes N. 35° E. and dips 60° S. E.

Several samples were tested from this property. No. 2138 represents the best material, and may be described as a white clay with yellow streaks. It is rather fine-grained, containing scattered grains of quartz. Under the microscope it shows an abundance of kaolinite scales, but scales of hydromica and grains of quartz are rather scarce. A few crystals of zircon were also present. Some portions of the clay show considerable quartz. No. 2138a is a washed sample of the preceding raw material (No. 2138). No. 2194 is second-grade clay.

* This same number is also used to indicate the location of a flood-plain clay, as the two are so close together as to prevent using separate numbers on the scale of map used.

Physical properties of clay: J. W. Goode's property.

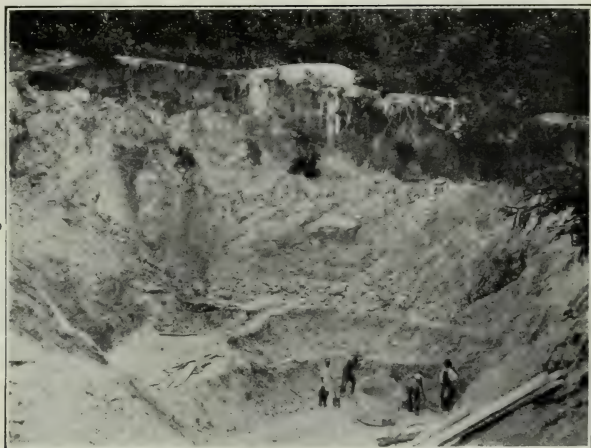
	2138	2138a	2194
Water required.....	50%	45%	45%
Plasticity	Good	Good	Good
Air shrinkage	8.6	9.3	8.8
Cone 010			
Fire shrinkage.....	....	....	3.4
Absorption .....	....	....	31.4
Cone 05			
Fire shrinkage.....	....	....	3.7
Absorption .....	....	....	31.6
Cone 1			
Fire shrinkage.....	9.7	7.3	8.6
Absorption	28.1	28.9	23.7
Cone 5			
Fire shrinkage.....	....	11.7	11.0
Absorption .....	....	15.0	15.0
Cone 7			
Fire shrinkage.....	....	....	11.0
Absorption .....	....	....	12.9
Cone 9			
Fire shrinkage.....	16.4	11.3	12.0
Absorption	7.76	11.5	12.1

All these clays burn cream white in color, and become steel hard at Cone 05. Except in the shrinkage and absorption at Cone 9, there is not much difference between the washed and the unwashed clay, although the former is a little less gritty.

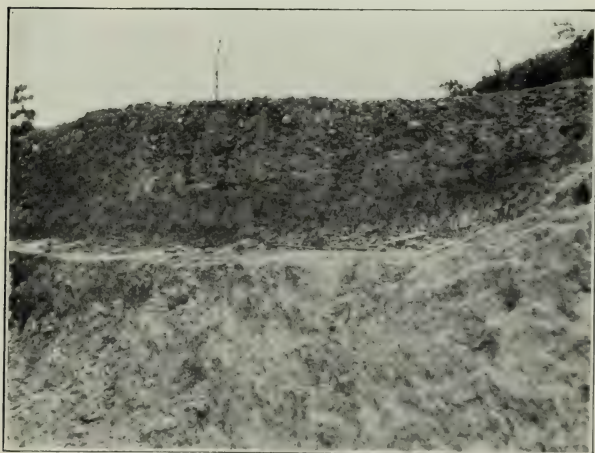
The following additional data obtained by us may be helpful to those who desire to prospect this area thoroughly. On the Marshall place, 2 miles southwest of Stuarts Draft (Field No. 17), white clay is said to have been found in a well, and in digging a cistern, in a swamp back of the house. Indeed it is asserted that the well, which is 64 feet deep, is all in white clay with the exception of a few feet at the top. The clay is said to have some yellow streaks, and some iron ore was also found in it.

Two miles east of Stuarts Draft, on the McDaniel place, a well 7 feet deep was bottomed in white clay. The samples that were shown us were white in color.

On the Rankin property, owned by W. J. Maupin, there is said to be a deposit of white clay southeast of the house. The overburden, which is similar to that at the Lofton deposit (p. 20), ranges from 8 to 17 feet in thickness. Under this there is an average thickness of 3 to 4 feet of white clay with a maximum thickness of 8 feet. It is underlain by yellow and chocolate-colored residual clay.



(A) White residual clay pit southeast of Cold Spring, Augusta County.



(B) Upper portion of same deposit showing character of overburden.



(A) Clay pit of Dickenson Fire Brick Co., Buena Vista, Rockbridge County.



(B) Limestone pinnacles in old open-cut workings, at zinc mine, Austinville, Wythe County.

Near here yellow residual clay shows in a stream, and a well put down at the time of our visit had penetrated 35 feet of the clay. This material (Lab. No. 2173) is very plastic, but is red burning. It had 5.2 per cent air shrinkage and burned steel hard at Cone 010. The fire shrinkage at both Cones 010 and 05 was 4.6 per cent, and the absorption 39.7 per cent at the lower cone, and 40.3 per cent at the higher cone.

Cold Spring.—On the mountain southeast of Cold Spring station is an old iron mine where residual limonite ore was obtained. A tunnel several hundred feet long was run into the pit, which cut through a considerable body of white clay (Field No. 18). Following the discovery of this a line of test pits was sunk for a distance of 500 or 600 feet in a south of west direction from the iron-ore pit, with the result that white clay was encountered in the test pits at depths of 3 to 20 feet below the surface, the overburden being mostly wash from the higher mountain slopes. Although these test pits were made as early as 1912, very little had been done toward developing the clay up to 1915. In the last three years the deposit has been actively worked and in 1918, one pit having a maximum depth of about 60 feet had been excavated, while a second one is being started. These pits are 600 feet above the Norfolk & Western Railway at Cold Spring.

There is no doubt that the material is of residual origin, but there is no bedrock exposed near it to show exactly what it might have been derived from, although it is probably residual from shale. This is indicated by a finely laminated structure which the clay shows in places. Most of the clay shows no pronounced bedding, is very dense, and when dry breaks off in a splintery manner. It is whitish in color, with an occasional faint pinkish tinge, and fracture planes in the upper part of the deposit may show some iron-oxide stains. These stains, however, seem to disappear with depth. Under the microscope the clay shows abundant scales of what appears to be kaolinite. Hydromica scales are also common, but quartz is scarce. A few grains of zircon were noted.

The clay (Lab. No. 2197) is very smooth, but slakes completely rather slowly. The water of plasticity is 39 per cent. Its plasticity is fair, and it has an air shrinkage of 5 per cent. When fired it burns to a cream-white color, but is not steel hard even at Cone 9, and the curious feature is its continuously high porosity, shown by the following firing tests:

Cone	Fire shrinkage	Absorption
010	3.6	32.7
1	4.3	31.4
5	6.3	27.1
9	6.6	24.0

This clay shows a curious composition, because of its low silica content, which is lower than is called for in kaolinite. It could probably be worked into mixtures made up for electrical porcelain or similar wares, its chief use is in paper and paint manufacture.

The composition of the clay is shown in the subjoined chemical analysis:

Chemical analysis of white clay near Cold Spring, Augusta County.

	Per cent
Silica (SiO_2)	43.31
Alumina (Al_2O_3)	39.42
Ferrie oxide (Fe_2O_3)	2.86
Magnesia (MgO)	.04
Lime (CaO)	None
Soda (Na_2O)	.30
Potash (K_2O)	.25
Loss on ignition	13.58
Total	99.76

The deposit is now worked by the Cold Spring Mining Company, of Baltimore, Md. A track 2.7 miles long, and having grades as high as 17 per cent, connects the pits with the mill at Cold Spring, a station on the Norfolk & Western railroad. The clay is brought down in cars hauled by a gasoline engine operating with the aid of a stationary cable.

The mill is located along the railway at Cold Spring Station. Here the clay is ground, dried and then passed through Raymond mills and separators. The product, of which over 99% passes 200 mesh, is used in the paper, paint, and rubber trade.

Lofton.—About half a mile northeast of Lofton and about 800 feet east of the Norfolk and Western Railway track is a swampy depression (Field No. 19) to the east of which is an old residual limonite mine. Underlying the swamp is a deposit of plastic clay which has an extent of not less than 15 acres. In places the clay comes almost to the grass roots, while in others there may be an overburden of 6 to 10 feet of sand and rounded cobbles of white quartzite, evidently some of the water-borne deposit that covers the valley floor in places. No bedrock outcrops in or immediately around the clay deposit, but along the railroad track about half a mile southwest of the swamp there are a number of exposures of bedrock, which are traceable along the track for about one mile. These begin just south of Lofton station, and consist of shales, sandstones, and limestones, as shown on the sketch map, Fig. 2. These beds strike in general N. 35° E., so that the clay is in the line of strike of the shale and sandstone beds just south of Lofton.

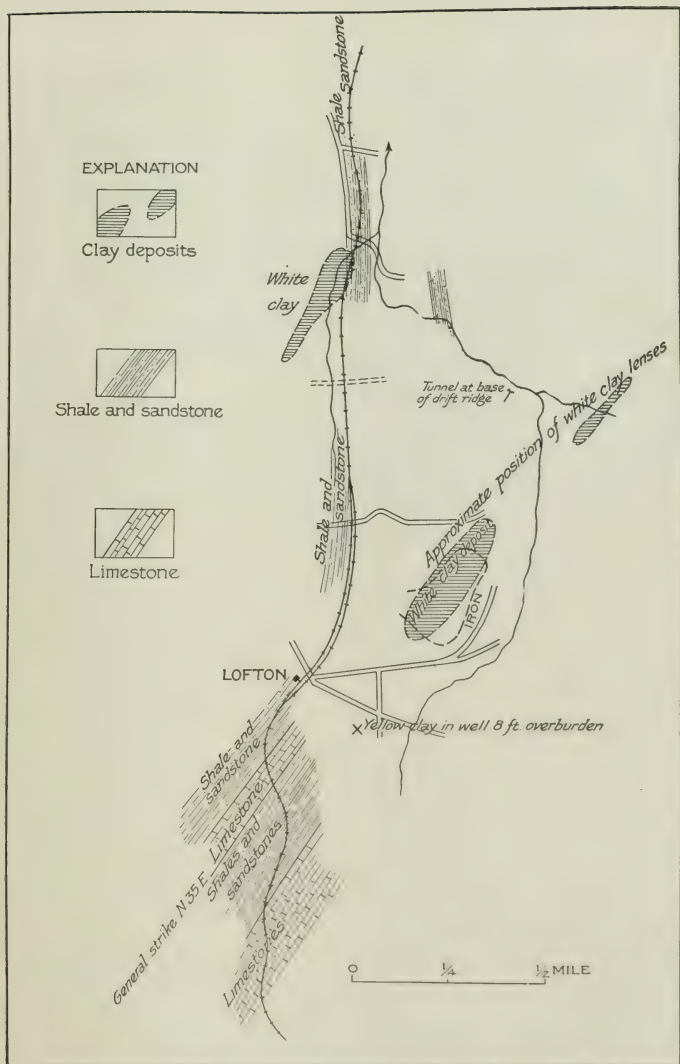


Fig. 2.—Sketch map of white residual clay deposit near Lofton, Augusta County, Virginia.

About 1 mile north of Lofton station, shale and sandstone can be seen along the track, but the strike of the beds is north and south.

The clay deposit is probably of residual character, and while it has been tested to a depth of not less than 40 feet no bedrock has been struck. In its upper portion the clay is grayish white, but grades downward into a light yellowish-brown clay, which has the same texture and feel as the white material.

One cannot avoid the conclusion that the white part of the clay has had the iron leached out of it by waters charged with organic acids that seeped down into it from the swamp. It should be added that the swamp is wet during only a part of the year, and could be easily drained by running a tunnel through the ridge on the east to carry the water off into a neighboring creek.

This clay is interesting, because it is one of the important deposits of white clay found along the east side of the valley between Basic and Buena Vista, but it differs in physical properties from any of the others, the difference being chiefly in its plasticity and dense-firing character.

A chemical analysis of the material yielded the following results:

Chemical analysis of clay near Lofton, Augusta County.

	Per cent
Silica (SiO_2)	52.10
Alumina (Al_2O_3)	31.54
Ferrie oxide (Fe_2O_3)	2.38
Magnesia (MgO)	.58
Lime (CaO)	.10
Potash (K_2O)	1.89
Soda (Na_2O)	.27
Water (H_2O)	10.89
Total	99.75

The analysis shows fairly high alumina, but a total of 5.22 per cent fluxes.

The clay (Lab. No. 2163) worked up with 47.7 per cent water to a mass of excellent plasticity, whose air shrinkage was 8.1 per cent.

The following are the results of some firing tests:

Temperature	Fire shrinkage	Absorption	Porosity
Cone 010	3.37	21.70	42.49
Cone 1	12.50	6.49	15.56
Cone 5	15.00	.18	.....
Cone 9	15.00	.16	.....

The clay fires steel hard at Cone 08, and develops a creamy-white color. The peculiar feature is the remarkably dense-burning character of the material, and its very high fire shrinkage. It is this high fire shrinkage which would preclude its being used alone, but it could be mixed with some white-burning clay of lower fire shrinkage and more open-burning character, for wares in which absolute whiteness was not an essential quality.

White clay is said to occur on the east side of the railroad about 1 mile north of Lofton station, but there are no exposures of it.

In the cut south of Lofton, where the shales are found, small amounts of residual clay are observed. They are of no commercial value, but are interesting in showing what kind of clay the shale yields on weathering. The clay developed here by weathering is mottled white, yellow, and brown, with occasionally a little red. The bedrock is not in evidence just here, but is probably shale.

Farther south in the cut there is more of the red clay, with lenses of cherty material, and some patches of white clay. Still farther south about 25 feet, greenish shale appears in the cottom of the cut, and is surrounded by banded yellow and brown clay, which has a sharp contact with the shale. The shale contains small streaks of white clay.

The few following figures show the relative physical properties of these clays:

	2176	2123	2124
Plasticity	Good	High	Fair
Water of plasticity.....	27%	35%	29%
Air shrinkage.....	5.2	7.4	6.8
Cone 010			
Fire shrinkage.....	2.3	1.3	1.6
Absorption	24.9	27.2	31.1
Cone 05			
Fire shrinkage.....	3.0	6.0	6.3
Absorption	22.8	17.7	16.6
Color burned.....	Red	Red	Red

No. 2176. Mottled clay from north end of cut.

No. 2123. Clay surrounding shale at south end of the cut and 6 feet from it.

No. 2124. Clay within 6 inches of shale.

There is not much difference between these clays. No. 2176 is more sandy, and hence more porous after firing.

Pekin.—On the T. L. Shelton property, 2 miles up (north) the Norfolk and Western Railway track, and northeast of Vesuvius, there is said to be a white clay deposit (Field No. 20), which is claimed has been proved by

boring to be 240 feet long and 28 to 30 feet thick. The width of the deposit is not known. It lies just above the iron-ore pits. The clay has fair plasticity. One sample burned at Cone 9 showed a total shrinkage of 10 per cent, 18.9 per cent absorption, was steel hard, and of cream-white color.

ROCKBRIDGE COUNTY.

Buena Vista.—Several openings have been made northeast of Buena Vista for mining brown iron ore, some of which show yellowish and whitish clays. In addition to these an opening has been made about $1\frac{1}{4}$ miles north of the station by the Dickinson Fire Brick Company (Field No. 30), which shows a large mass of white clay, with only a small quantity of associated iron ore (Plate III, A).

The clay is whitish, and varies from fine-grained to gritty material. Scattered through it are occasional chert fragments suggesting that the clay has been derived from limestone. The face of clay exposed in the bank was about 18 feet high, and a boring made in the center of the pit has shown 25 feet additional thickness. Furthermore, borings made to the south of the excavation have also shown white clay. The overburden consists of cobblestones and dirt, and was 2 to 4 feet in thickness.

The clay may show iron-oxide stains, especially in the upper part, but these seem to be due to seepage along joint planes. Mineralogically it consists chiefly of kaolinite and hydromica, with considerable quartz.

One sample tested was of the run of clay as it comes to the mill and after it had been ground. This clay (Lab. No. 2181) was smooth, and worked up with 28 per cent of water to a mass of good plasticity, whose air shrinkage was 4 per cent.

The firing tests of the wet-molded bricklets were as follows:

Cone	Fire shrinkage	Absorption
010	3	27.7
03	1	23.0
1	4	16.55
5	6.0	11.70
9	6.6	12.00
27	Fused	.....

The clay gives a fair brick at Cone 010, even though its absorption is high, and is nearly steel hard at Cone 03. It burns cream in color. This material makes a good fire brick, and is used for that purpose. It could also be used in saggers.

A sample taken from the bank and burned only at the lower cones was very similar in its behavior. It required 30 per cent of water for mixing, gave good plasticity, and had 4.8 per cent air shrinkage.

At Cone 010 the fire shrinkage was 0 per cent, and the absorption 25.8 per cent, while at Cone 05 the shrinkage and absorption were 0 per cent and 26.2 per cent, respectively.

To the northeast of the plant there is a line of pits extending for about a mile in a northeast direction. They were all opened for iron ore, but every one shows at least some white clay. No large body of clay has been exposed at any point. The clays exposed are refractory and could be used in fire bricks, saggars, or similar wares.

One mile north of Buena Vista station, on what is known as Mineral Ridge (Field No. 30), a large cut was made in search of iron ore. The clay exposed in the walls is mostly of a ferruginous character, but on the west side of the cut there is a pocket of white clay, not less than 20 feet in thickness, and containing angular chert fragments. The length of the pocket cannot be determined as part of it is covered by slide material. It is similar in appearance to the clay worked in the pit of the Dickinson Fire Clay Company, and shows the same principal minerals when examined under the microscope. The physical properties are also similar to those of the Dickinson fire clay, as seen by the following few tests made on it.

Clay (Lab. No. 2183), very smooth; water required, 30 per cent; plasticity, good; air shrinkage, 4 per cent; Cone 010: fire shrinkage, 0 per cent, absorption, 23.8 per cent; Cone 05: fire shrinkage, 0 per cent, absorption, 25.4 per cent; color after firing, cream-white; not steel hard.

On the east and north side of the cut there is yellowish and more gritty clay. It is identical with the preceding one as to water required for mixing and plasticity, but differs somewhat otherwise as one might expect from its gritty nature. Thus the air shrinkage is only 3.6 per cent, while the absorption at Cone 010 was 46.5 per cent, and at Cone 05, 27.5 per cent. The clay burns light yellowish-red. The deposit is approximately in the line of strike of the other pits.

Another deposit of whitish clay was seen on the Glasgow property, adjoining the Norfolk and Western Railway tracks on the east, about 2 miles northwest of Buena Vista (Field No. 31).

A cut in the railroad near-by shows some white clay and a closely associated, partly weathered dolomite, which may be the parent rock. About 200 feet south of this on the east side of the track, as already noted, there is a small outcrop of whitish clay of exceeding toughness. An area about 40 feet long and 15 feet wide was tested with the auger, and holes put down to a depth of 9 feet, but, owing to the extreme toughness of the material, even these were made with difficulty. There also appeared to be granular rock

fragments in the deposit. The clay as a whole was grayish white, but some of it was mottled. We have no definite knowledge regarding the areal extent of this material, and more test pitting is needed to prove it. It may be said that a 70-foot well put down about 100 feet north of where the borings were made is claimed to have penetrated 66 feet of whitish clay.

A few partial tests made on the material show that it is more like the yellow clay in the Mineral Ridge pit than like that at the fire-brick works.

The material (Lab. No. 2154) is gritty, required 38 per cent of water for mixing, and had good plasticity. Its air shrinkage was 5.9 per cent. At both Cones 010 and 05 it had a fire shrinkage of 1.3 per cent, and the absorption was close to 31 per cent. It fired to a light-red color, and is probably not a refractory clay.

The table on p. 27 gives in summarized form the tests made on the white residual clays derived from the Cambrian shales. It will be observed from these tests that none of them fire white, although they are white or gray-white in their raw state. They also show a variation in fire shrinkage and absorption. Only one, that from Lofton, fires to a very dense body, and in this case the fire shrinkage is too high to permit of the material being used alone.

CAMBRIAN SHALES OF MIDDLE-WESTERN VIRGINIA.

WATAUGA SHALE.

The Watauga shale formation, which is Cambrian in age, lies near the base and just above the Shady Dolomite of the Cambro-Ordovician section along the eastern side of the Great Valley. Although an extensive shale formation, outcrops are not very abundant. They can be seen north of Basic, around Lithia, and are worked around Glasgow.

AUGUSTA COUNTY.

Basic.—Traveling northward from Basic along the line of the Norfolk and Western Railroad there is in the first mile or two evidence of shale rock, but most of it is very gritty. In places it has weathered to a residual clay, at one of which it can be seen along the road about half a mile north of Basic (Field No. 24). The material (Lab. No. 2193) is a very plastic residual clay, of red-burning character. It has 5.8 per cent fire shrinkage, 0 to 1 per cent fire shrinkage up to Cone 05, and about 20 per cent absorption. At best it is to be classed as a common-brick clay. Without borings or test pits there is no means of telling how deep the weathered shale extends, or what the characters of the unweathered shale are.

About one mile southeast of Basic (Field No. 21), where the wagon road crosses the Chesapeake and Ohio Railroad, the Cambrian shale outcrops along both the wagon road and the railroad. The material is very gritty, but not very hard. Its plasticity is very low, and the shale (Lab. No. 2265) is not adapted to the manufacture of clay products. Small samples can, of course, with care be molded into bricklets, but it would not work on a large scale.

ROCKBRIDGE COUNTY.

Vesuvius.—In a cut on the Norfolk and Western Railway, just north of Vesuvius (Field No. 29), there are greenish-gray fissile shales overlain by a varying thickness of cobbly overburden.

The shale is fairly soft, and breaks off easily into splintery fragments, which in part cover the outcrop. It weathers into a clayey material, which in places grades upward into a white clay with limonite stains. The shale strikes N. 80° W. and dips 40° S. It probably does not extend very far west of the railway, as we saw no outcrops of it, while between Midway and Vesuvius there are numerous outcrops of the Natural Bridge limestone, with an easterly dip.

The only material in the cut deserving consideration from the commercial standpoint is the shale, though we have no definite means of knowing how much there is because of the mantle of overburden which conceals it.

The shale (Lab. No. 2165) is gritty, and of very low plasticity, so that it could not be worked alone. Its average air shrinkage is 5 per cent, and it shows 12.3 per cent absorption at Cone 05, with reddish color. If any limestone residual clay were worked near here, and it was desired to mix a material of lower shrinkage, the shale could be used for this purpose; or if there was residual clay over it, probably 25 per cent of shale could be mixed with it. It could be used only for brick.

The slightly-weathered shale (Lab. No. 2175) is somewhat more plastic, but still gritty, and has an air shrinkage of 1.8 per cent. Curiously enough at Cone 010 it burns to a hard brick with 1.7 per cent fire shrinkage and 10.4 per cent absorption, while at Cone 05 the fire shrinkage is 3 per cent and absorption 7.63 per cent. The color after firing is red.

Taking the yellow residual clay derived from the shale, this is so different that, if there were enough of it to work, it would be greatly improved by adding some of the fresh or slightly weathered material. It (Lab. No. 2164) has good plasticity, but an air shrinkage of 8.2 per cent.

If fired to Cone 010 the fire shrinkage is 0.6 per cent and absorption 30.9 per cent, while at Cone 05, with 5.7 per cent fire shrinkage, the



General view of brick plant of Glasgow Clay Products Corporation, near Glasgow, Rockbridge County, Virginia. (Photo by Glasgow Clay Products Corporation.)



(A) Cut in Cambrian shale worked by the Glasgow Clay Products Corporation, near Glasgow, Rockbridge County, Virginia. (Photo by Glasgow Clay Products Corporation.)



(B) General view of kilns of the Glasgow Clay Products Corporation, near Glasgow, Rockbridge County, Virginia. (Photo by Glasgow Clay Products Corporation.)

absorption is still high, namely, 25.6 per cent. Its absorption is too high to use the material alone, even if there is enough of it.

Lastly the whitish clay with iron-oxide stains (Lab. No. 2174) burns red, like the others, and has good plasticity, but low air shrinkage, namely, 2.4 per cent. It shows no shrinkage at Cone 010 and 4.4 per cent at Cone 05, while the absorption at these two cones is 16.8 and 17.8 per cent, respectively.

Buena Vista.—Efforts were made to ascertain the value of Cambrian shales east of Buena Vista, but few outcrops were found. What little was observed is hard and gritty.

Glasgow.—The Watauga shales (Field No. 111), are being utilized at this locality by the Glasgow Clay Products Corporation for the manufacture of common brick. The geologic relations are shown in the sketch section Fig. 3, from which it will be seen that the northwesterly dipping shales are associated with the Shady limestone.

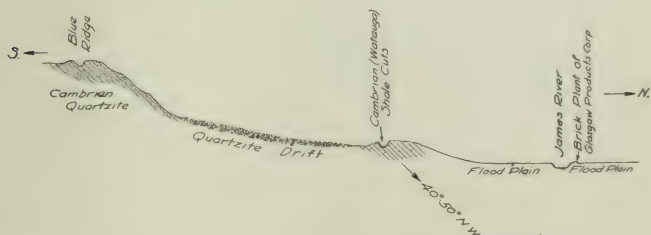


Fig. 3.—Generalized section from brick plant of Glasgow Clay-Products Corporation near Glasgow south to Blue Ridge Mountains, showing relations of Cambrian shales used for brick-making.

The shale which is quarried on the south side of the river is of purple, yellow and buff color, and has been more or less softened by weathering, this change extending to a depth of at least 50 feet.

Several cuts have been excavated in the shale, and these are aligned along approximately a northeast-southwest direction. The northeast cut in April, 1920, was 250 feet long, 100 feet wide, and had a maximum depth of 50 feet; the strike of the shales here is N.50°E. and the dip N.40°-50°N.W. Purple shales predominate in this opening.

The southwest cut is about 100 feet long, 50 feet wide and 20 feet deep, the strike and dip of the shales being the same as in the northeast cut. The

character of the shales is also the same, except that approximately 4 feet of limestone beds are interbedded with the shale at a depth of 10 to 12 feet. The limestone is discarded.

The shale is fairly plastic when ground and mixed with water. Its air shrinkage is 2 per cent and tensile strength 31 pounds per square inch. It fires to a red color, and gives a good brick, but has a rather short firing range. The fire shrinkage at Cone 05 is 5 per cent and absorption 7.1 per cent. The clay is overfired at Cone 1.

It gives a good brick, but is of doubtful value for fireproofing.

The shale from the open cuts (Plate V, A), is taken to the works across James River by means of a tram and cableway, and delivered to the storage shed. It is ground in dry pan, tempered in pug mill, and molded in stiff-mud machine. From this the molded bricks pass through drying tunnels, and are then fired in circular down draft kilns (see Plates IV and V, B). The plant has an annual capacity of 7 to 8 million brick.

BOTETOURT COUNTY.

Lithia.—Along the wagon road about one mile both north and south of Lithia (Field No. 48) there are outcrops of red, brown, and dark gray shale. It (Lab. No. 2237) appears hard, and not very promising, but, nevertheless when ground up and mixed with 18 per cent of water, it gives a mass of very fair plasticity; indeed as much so as some shales that are worked through a stiff-mud machine. The air shrinkage is low, 3 per cent, as is the tensile strength, which is only 25 pounds per square inch. Nevertheless the material can be molded without much difficulty, because, although granular, the fine particles are very sticky. It was fired with the following results:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0	Too soft
05	2	8.6
1	7	5.0
3	5	6.7
5	Overfired and swelled	

The clay has a rather short heat range, but it burns to a hard brick of rather low absorption at Cone 05. The color after burning is red. It could be used for brick and probably hollow blocks.

CAMBRIAN SHALES OF SOUTHWEST VIRGINIA.

NOLICHUCKY SHALE.

This formation occurs in southwest Virginia, both in the Valley region proper and west of Moccasin ridge. As a whole the formation is described by Bassler^a as a calcareous greenish to olive shale and shaly limestone reaching a maximum of 400 feet in thickness. The occurrence of the limestone beds seems to be somewhat irregular, so that at times considerable shale could be excavated without having to throw out a very large amount of lime rock. While the formation is somewhat widely distributed in southwestern Virginia, it is not always well located for working, even if otherwise desirable.

We sampled it at only two localities, namely, near Blacksburg, Montgomery County, and near Castlewood, Russell County.

MONTGOMERY COUNTY.

Blacksburg.—Two miles west of north from Blacksburg, on a branch of Toms Creek, and half a mile north of the Broce house (Field No. 60), the Nolichucky shale can be seen outcropping in the hill along the road, with a probable width of between 100 and 150 feet. It can also be traced southwest along the strike to the next wagon road. Where exposed it is a hard, fine-grained, smooth shale, free from limestone layers, and covered by about 6 feet of residual clay. When examined under the microscope the shale appears to be made up chiefly of grains of calcite and hydromica, with a little quartz. The limestone outcrops just north of the shale and has about 10 feet of residual clay overburden. Only the shale was tested.

This (Lab. No. 2300) gave a mixture of moderate plasticity with 17 per cent of water. The air shrinkage was 3.2 per cent, and the average tensile strength 40 pounds per square inch. The fire shrinkage at both Cones 010 and 05 was 0 per cent, and the absorption 19 per cent. It gave a speckled pink brick that was too soft at Cone 010, but of fair hardness at Cone 05. At Cone 1 the absorption was similarly high. The clay would no doubt give much better results if mixed with 15 or 25 per cent of the overlying clay. The light spots in the clay are probably due to calcareous material. The shale, if mixed with the residual clay, could be used for brick if properly fired.

^a Bassler, R. S.: The cement resources of Virginia west of the Blue Ridge, Va. Geol. Survey, Bull. 11-A, 1909, p. 151.

RUSSELL COUNTY.

Castlewood.—About $3\frac{1}{2}$ miles north of Castlewood, on a horseshoe curve of the wagon road to Dante, there are several good exposures in the Nolichucky shale (Field No. 88). Here it shows as a fissile brown shale, with occasional limestone bands, but not enough to interfere with the utilization of it. The shale crosses both bends of the horseshoe and appears on the other side of the hill, there being apparently a considerable quantity of it.

Where the sample (Lab. No. 2367) was taken the outcrop was about 200 feet long and 15 to 20 feet high. At each end of the section the material is more sandy. The haul from here to Castlewood is nearly all downhill. Although the shale is very hard it makes a fairly plastic mass when ground up with water. The tensile strength, 25 pounds per square inch, is not high; the air shrinkage, 3.7 per cent, is low.

One sample was put through the stiff-mud machine, and flowed through the die without any trouble, which was contrary to what we expected from the physical nature of the raw material. There is evidently considerable lime scattered through the shale, for the stiff-mud bricks fired at Cone 010 had disintegrated in the laboratory in about 3 days, due to the hydration of the lime specks. Those that were fired at Cone 05 were steel hard, deep pink in color, and did not slake. A wet-molded bricklet fired at Cone 1 had 1.5 per cent fire shrinkage, and 10.5 per cent absorption.

The shale can be used for brick if fired sufficiently hard, but it is inferior to the shale of the Russell formation found along the railroad.

The Nolichucky shale is found to the southwest in the area of the Bristol folio of the United States Geological Survey. Thus a narrow band of it is crossed by the Norfolk and Western Railway about a mile or so northeast of Bristol, and also by the Virginia and Southwestern Railway southeast and northwest of Abrams Falls. In the vicinity of Abrams Falls the formation consists of calcareous shale and beds of impure shaly limestone. The shale is blue when fresh, but weathers readily to yellow, green, and brown.

RUSSELL FORMATION.

This is best exposed in Russell County. It is said to consist generally of alternating thin bands of shale, sandstone, and impure limestone of various colors, but with a prevailing tint of red or reddish-brown. The upper part of the formation is a thick bed of brown, slightly calcareous shale, which gradually passes into the mixed beds described above. The beds show numerous minor crumplings, hence their thickness is difficult to determine.

One of the most accessible areas is a belt lying on the northwest side of the Norfolk and Western Railway, beginning at Castlewood and extending northwestward past Kiser, Russell County. Another belt extends in a northeast-southwest direction across Scott County, and lies mainly on the northwest side of the railroad running northeast from Clinchport. A small area also lies about half a mile northwest of Witten Mills, Tazewell County, on the Clinch Valley branch of the Norfolk and Western Railway.

Samples of the shale were taken at two localities, namely, Kiser and Honaker in Russell County. The tests made on them show that they can be utilized in the manufacture of brick.

RUSSELL COUNTY.

Kiser.—The shale exposed in the cuts at Kiser (Field No. 89) is much crumpled, and so glossy that it has a schist-like appearance. It does not weather down easily, and often may not furnish enough soil for grass. However, when the shale (Lab. No. 2361) is ground to pass a 20-mesh sieve, and mixed with 21 per cent of water, it gives a mass of moderate plasticity, whose air shrinkage is 3.3 per cent, and average tensile strength 23 pounds per square inch.

The fire tests were as follows:

Cone	Fire shrinkage	Absorption
010	0%	13.6%
05	1.7	7.4
1	4.7	3.8
3	1.7	Overfired

The shale fired to a red color, and was steel hard at Cone 05.

The same material was also tried dry press with good results, for at Cone 05 it gave a brick with 1.3 per cent fire shrinkage, and 10 per cent absorption, while at Cone 2 the absorption was 3.6 per cent.

Carterton.—Here the Russell shale is also exposed, there being a cut at the station about 200 feet long and 40 feet high (Field No. 90). It contains a bed of unbroken limestone, which could easily be removed in mining. No sample was tested.

Castlewood.—Here again the shale outcrops in the railway cut (Field No. 91), and is practically identical with the Kiser material. It is not in a good location to work and was not sampled.

Honaker.—The Russell shale can be seen on the main road about a quarter of a mile northwest of Honaker (Field No. 92) in a cut about 15

feet deep, but it is quite gritty. The sample (Lab. No. 2365) collected here developed so little plasticity even after fine grinding that the test was carried no further.

CAMBRO-ORDOVICIAN FORMATIONS.

The Cambro-Ordovician rocks, including the Shenandoah Group of limestones and shales, form the floor of the Great Valley. They extend entirely across the State in a general northeast-southwest direction forming an important belt of rocks parallel to and immediately west of the Blue Ridge.

Berryville, Winchester, Harrisonburg, Staunton, Lexington, Roanoke, Radford, Wytheville, Abingdon, and Bristol are situated in this belt, but the more exact outline of the area can best be understood by reference to the geologic map of the State. The rocks of this group consist of limestones and shales, with the former predominant. The limestones as such are, of course, of no value for the manufacture of clay products, but the residual clays derived from them are useful.

The shales, of which there are several, yield in all cases a residual clay that can often be used in the manufacture of clay products. In some instances the shales can be utilized in their nearly fresh state. Of these we have (a) the Watauga ("Buena Vista") shale found chiefly along the east side of the Great Valley, (b) the Athens shale found only in southwestern Virginia, (c) certain shaly members of the Natural Bridge limestone which are prominent in the region between Roanoke and Buchanan. The last named are not very promising in their fresh condition, but yield a tough residual clay, which will stand the admixture of a considerable amount of the fresh shale; (d) the Nolichucky and Russell shales of southwest Virginia, and (e) the Martinsburg shale of northern and west central Virginia.

The shales of Cambrian age have been discussed in the preceding pages.

Physical tests of Nolichucky shale, Montgomery and Russell Counties, Virginia.

Laboratory Number	Field Number	Locality	Water plasticity	Plasticity	Tensile strength	Air shrinkage	Cone 010		Cone 05		Cone 1		Color
							Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	
2360	60	Blacksburg, 2 m. n. w.....	17.0	Fair	40.0	3.2	.0	19.0	....	....	....	....	Pink
2367	88	Castlewood, 3½ m. n.....	20.0	Fair	25.0	3.7	....	....	....	....	1.5	10.5	Pink

Physical tests of Russell shale, Russell County, Virginia.

2361	89	Kiser	21.0	Fair	25.0	3.3	.0	13.6	1.7	7.4	4.7	3.8	Red
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The correlation of the shale and limestone members of the Cambro-Ordovician formations in northern, west-central, and southwestern Virginia^a may be tabulated as follows:

	Northern Virginia	West-Central Virginia	Southwestern Virginia
Ordovician	Martinsburg shale	Martinsburg shale	Sevier shale
	Chambersburg limestone	Liberty Hall limestone	{ Moccasin limestone Athens shale
	Stones River limestone	Murat limestone	Chickamauga limestone, including Holston
	Beekmantown limestone		Knox dolomite
	Conococheague limestone	Natural Bridge limestone	Nolichucky shale
Cambrian	Elbrook limestone		Honaker limestone
	Waynesboro shale	Watauga shale ("Buena Vista")	Watauga shale
	Tomstown limestone	Shady limestone ("Sherwood")	Shady dolomite
	Harpers shale	Hampton shale	Hampton shale

The Cambrian and Ordovician materials are taken up separately with the exception of the clays associated with the Shenandoah group of limestones.

RESIDUAL CLAYS FROM CAMBRIAN SHALES IN GREAT VALLEY PROVINCE OF SOUTHWEST VIRGINIA.

ROANOKE COUNTY.

Rorer Mines.—These brown-ore mines lie 3 miles south of Roanoke (Field No. 55). The limonite is mostly in iron-stained clay and sand, but there are streaks and bunches of gray clay, the latter sometimes 6 feet in diameter.

The material (Lab. No. 2369) is plastic and buff-burning, but there is hardly enough to make it worth working. If pockets large enough to work were found, it might possibly be used in saggars, or sold to steel works.

PULASKI COUNTY.

Hirassee.—The Cambrian shales underlie the Cambro-Ordovician limestones, and in Pulaski and Wythe counties form a belt together with the

^a Based on data of the State and Federal Surveys. For west-central Virginia see Campbell, H. D., Amer. Jour. Science, 1905, (4) XX, pp. 445-447.

Erwin quartzite and Unicoi sandstone lying between the limestones on the northwest and the pre-Cambrian granites and gneisses on the southeast. In the vicinity of Hiwassee and Foster Falls they lie quite near the railroad. These shales, when fresh, appear quite hard and gritty, so that they are of no value for making clay products, but weathering softens them down to a smooth plastic material which may show a variety of colors.

A good section of the fresh shale is seen about half a mile northwest of Radford Furnace, Pulaski County (Field No. 64), where the hard, steep, east-dipping beds of different colors can be observed. This material (Lab. No. 2121) is too gritty and develops no plasticity. A still better section of the hard shales and associated limestones is seen along Mack's Creek.

A good example of the weathered material can be seen along the road from Hiwassee station leading over the ridge to the Hibernia mine, a mile southwest of Hiwassee (Field No. 65). The material (Lab. No. 2118), although still showing the bedding of the shale, is soft, but dense. It is gritty in places, and, while mostly of a deep red-brown color, contains occasional streaks of yellow. The material worked up with 27 per cent water to a mass of high plasticity. It had but 25 pounds tensile strength when dried. The air shrinkage was 4.6 per cent. Burning tests gave the following results:

Cone	Fire shrinkage	Absorption
010	.4	17.4
05	1.0	17.4
03	6.7	4.9
1	7.2	4.6
3	5.4	0

The clay burns red, is not steel hard until between Cones 05 and 03, and begins to overfire at Cone 3.

It should make a good brick at Cone 05.

In places the shale has decomposed to a very smooth, fine-grained red or yellow clay, having the character of ocher, and at one time a factory was erected one mile southwest of Hiwassee to utilize the material for mineral paint.

In addition to the Cambrian shales just referred to there are white and yellow clays in some of the brown iron-ore pits: the pockets of this material being similar to those described near Ivanhoe (p. 49).

As numerous inquiries have been made regarding these, a few localities observed may be mentioned. They are:

Hibernia mine, about one mile southwest of Hiwassee (Field No. 65). Here we have a grayish-white sandy clay (Lab. No. 2024), with yellowish

mottlings exposed in the southwest wall of the old pit. The mass as exposed is probably 20 feet high and 40 feet long, but it is not known how far it extends into the bank. It seems to overlie the ore. Another mass is a shaly clay of yellowish-white color (Lab. No. 2053) which dips west of south and is said to underlie the ore body. No accurate estimate can be made of it. A few preliminary tests were made on these materials and are given below:

	No. 2024	No. 2053
Plasticity	Fair	Fair
Water required.....	27%	34%
Air shrinkage.....	5%	5.1%
Cone 010		
Fire shrinkage.....	0	.7
Absorption	21.6	31.6
Cone 05		
Fire shrinkage.....	.6	2.7
Absorption	19.4	29.4
Cone 1		
Fire shrinkage.....	4.3	....
Absorption	12.7	....
Cone 3		
Fire shrinkage.....	7.3	....
Absorption	8.4	....
Cone 5		
Fire shrinkage.....	8.0	....
Absorption	7.4	....
Color burned	Buff	Pink
Steel hard cone.....	1	05

The clay might be used in stove brick or saggers, but the supply is not large.

WYTHE COUNTY.

Foster Falls.—There are several exposures of yellow and white clays exposed near the southwest end of Dry Pond Mountain, and about 2 miles southeast of Foster Falls (Field No. 68), but they are all of limited extent and require test pitting or boring to determine their extent. They are similar in appearance to those found in the iron-ore pits to the southwest.

One of these deposits is exposed in the creek bottom on the southwest base of the mountain. Under the microscope it shows abundant grains of hydromica. Kaolinite and quartz are common. Grains of tourmaline, zircon, and titanite are present, but they are scarce. It (Lab. No. 2144) is white with yellow streaks. The clay is highly plastic, and fires to a cream color at Cone 1. The air shrinkage is 3.8 per cent. The fire shrinkage at

Cones 010 and 05 is zero, while at Cone 1 it is 7.4 per cent. The absorption at these three cones is 30, 30.4, and 13 per cent, respectively. The exact quantity of the material is unknown.

Another outcrop of red and yellow clay (Lab. No. 2145), exposed for a distance of 20 feet in the same branch, is so sandy that even at Cone 05 it does not fire to a hard body, but could probably be mixed with the preceding for use. Near here is an abandoned iron-ore pit, but the clay in it (Lab. No. 2143) is all red burning.

To the southwest of the ore pit in another branch is a large quantity of red clay, which shows a shaly structure and is red burning, but this grades into a yellow and white clay (Lab. No. 2097), which fires cream-white at Cone 05 with 27.9 per cent absorption.

Some of the residual clay of this area is very fine-grained and is said to make a fair grade of ocher.

RESIDUAL CLAYS FROM CAMBRO-ORDOVICIAN LIMESTONES.

The Cambro-Ordovician limestones weather to a ferruginous plastic clay, which sometimes is exposed in natural or artificial cuttings, but at others, although present, may be covered by a growth of vegetation. Samples were collected at a number of localities where the material is exposed. Similar clays will no doubt be found at many other places by test pitting or boring. Owing to the irregular thickness the clays should in every case be carefully prospected.

CLARKE COUNTY.

Berryville.—This town lies in the middle of the limestone belt, and considerable residual clay of red and yellow color overlies the limestone. Small samples for preliminary tests were taken from several localities where there were good exposures. One of these was 3 miles southeast of Berryville (Field No. 3) in a cut along the road. The material is red and yellow residual clay, of good plasticity, and not gritty, which, under the microscope, is seen to consist chiefly of hydromica, kaolinite, and quartz, with rather common grains of biotite. It required 34 per cent of water to work it up, and it had 7.9 per cent air shrinkage. The clay (Lab. No. 2217) burns to a good red color and is steel hard at Cone 05, but even at Cone 010 it would make a fair brick. The fire shrinkage at the lower cone is 0 per cent, and absorption 21.0 per cent, while at the higher cone the fire shrinkage is 6.4 per cent, and absorption 7.4 per cent. There seems no reason why this should not make a good brick.

Between this point and the Shenandoah River there are some shaly beds in the limestone, but they are of doubtful value in their unweathered condition, and they may be of limited extent.

A short distance south of the above locality are cuts showing residual clay derived from shaly layers in the limestone. This material, which is similar in mineral composition to 2217, is yellowish-brown, plastic, and smooth. It (Lab. No. 2218) worked up with 20 per cent water, and had an air shrinkage of 7.2 per cent. At Cone 010 the fire shrinkage was .3 per cent, and absorption 20.2 per cent. At Cone 05 these values were 4.7 per cent and 11.3 per cent, respectively. It is, therefore, not quite as dense burning as the preceding clay, but would make a good brick material, for it gives a good red body after burning, and becomes steel hard at Cone 05.

SHENANDOAH COUNTY.

Strasburg.—In the region northwest and west of Strasburg the limestone seems to lie quite close to the surface, with little residual clay, and the same appears true for a distance 2 to 3 miles north of Strasburg. Just northeast of the town (Field No. 5) there is an old brickyard which used to work the residual material and made stiff-mud bricks from it. This clay (Lab. No. 2220) had excellent plasticity, and worked up with 26 per cent of water. The bricklets made from it had 6.7 per cent air shrinkage. At Cone 010 the fire shrinkage was 0 per cent, and absorption 18.6 per cent, while at Cone 05 these values were 2.4 and 12.4 per cent, respectively. The bricklets were steel hard at Cone 05. There seems no objection to using this for making a good common brick.

WARREN COUNTY.

Front Royal.—Front Royal lies in a flat valley with the hills rising rather abruptly to the south, and there are no good clay exposures near town, at least, in the valley road cuts. The hill roads show clay cuts, but the material appears to be of doubtful value. Clay shows in a few small railroad cuts between Riverton and Front Royal, but it is mostly stony.

Riverton.—There are many limestone exposures, but residual clay does not appear to be abundant. One of the best cuts exhibiting clay is immediately back of Riverton station (Field No. 4). This (Lab. No. 2219) is a reddish-brown clay containing abundant grains of quartz, with considerable kaolinite and hydromica. A little tourmaline and zircon are present. The material is smooth and of excellent plasticity. It worked up with 27 per cent water, and had 7.3 per cent air shrinkage. At Cone 010 the fire

shrinkage was 0 per cent, and absorption 17.4 per cent, while at Cone 05 these were, respectively .7 and 15 per cent. The clay burns red and becomes steel hard at Cone 05. It could be used for common brick.

ROCKINGHAM COUNTY.

Elkton.—This town lies on the eastern edge of the Cambro-Ordovician belt, which extends along the eastern side of Massanutten Mountain. There is not much residual clay in evidence, as much of it appears to be covered by wash, which may have some of the residual clay mixed with it. Some of this is well shown $1\frac{1}{2}$ miles southeast of Elkton station (Field No. 10). The material (Lab. No. 2221) is a gritty, pebbly clay of fair plasticity, which works up with 22 per cent of water, and has 5.2 per cent air shrinkage. At Cone 010 the fire shrinkage is .3 per cent, and absorption 17 per cent, while at Cone 05 it is practically the same. It is nearly steel hard at Cone 05 and burns red. This clay could be used for brick, but is not as good as the residual material, free from wash.

Harrisonburg.—Residual clay can be obtained at a number of points around Harrisonburg, and it has been utilized in a small way. The location is favored by being at the intersection of two railways. One residual deposit formerly worked lies half a mile north of town.

At C. C. Conrad's yard, half a mile northeast of Harrisonburg (Field No. 11), the residual clay is used for brick. The plant is very simple, the brick being hand-molded, sun-dried, and burned in a scove kiln, which does not give a very hard product. If properly fired the clay will make a good brick. Here there are two clays, namely, an upper one referred to as top soil (Lab. No. 2223) and a lower one or red clay (Lab. No. 2222). These are quite different in their properties, as can be seen by comparing the two sets of figures given below:

	Plas- ticity	Water	Air shrinkage	Cone 010		Cone 05	
				Fire shrinkage	Ab- sorption	Fire shrinkage	Ab- sorption
Top soil	High	27	5.3%	.3	21.2	.3	22.2
Red clay	High	25	8.2%	.7	15.7	4.0	10.7

The clay gives a denser body, while the top soil being more gritty gives a more porous body of lower shrinkage. The two, therefore, make a good mixture. Both fire red.

One-half mile east of Harrisonburg is Billheimer's yard (Field No. 12), which was operated up to about 1914. The residual clay here (Lab. No. 2224) is yellow to red and plastic. It had 8.3 per cent air shrinkage when tested in the laboratory, and burned to a good red brick. At Cone 010 the fire shrinkage was .3 per cent, and absorption 23.6 per cent, while at Cone 05 the fire shrinkage was 6.3 per cent with an absorption of 18 per cent. The brick is hard even though its absorption is not very low.

Dayton.—Stiff-mud brick are being made at this locality by Shrum Brothers (Field No. 13). The material (Lab. No. 2225) is residual from the Cambro-Ordovician limestone, but has probably been reworked a little by rain wash. There are also some shaly streaks in it. The clay shows red, black, and brown varieties, and these are more or less mixed. It possesses excellent plasticity, and works up with 29 per cent of water. The air shrinkage is 7.7 per cent, and the average tensile strength when air dried is 247 pounds per square inch. At Cone 010 the fire shrinkage is 0 per cent, and the absorption 20.8 per cent, while at Cone 05 there is 4 per cent fire shrinkage, and 10.8 per cent absorption. Fired at Cone 05 the clay makes a good hard brick of red color. It also worked well dry press.

AUGUSTA COUNTY.

Stuarts Draft.—The residual clays from the Cambro-Ordovician limestones underlie portions of the Valley bottom, and are exposed at several places north of Stuarts Draft. They closely resemble those derived from similar rocks to the north and south of Stuarts Draft, but may vary somewhat in their physical characters from place to place.

The following partial tests of two from north of Stuarts Draft (Field No. 112) show some difference:

	Lab. No. 2136	Lab. No. 2137
Water of plasticity.....	27%	27%
Plasticity	High	High
Air shrinkage.....	7.7	7.4
Firing tests:		
Cone 010		
Fire shrinkage.....	6.40	3.4
Absorption	9.09	19.7
Cone 05		
Fire shrinkage.....	8.70	9.0
Absorption	6.89	7.78
Steel hard.....	Cone 010	Cone 010
Color	Red	Red

Both clays fire to a good brick at Cone 010, but, as will be seen from the tests, the No. 2136 fires to a denser body than No. 2137.

Staunton.—Lying chiefly west of the city is a broad area underlain by Cambro-Ordovician limestone, which yields residual clay at different points.

One mile northeast of Staunton is the brick plant of T. J. Lohr (Field No. 22), in whose bank the residual clay has been dug to a depth of 2 to 3 feet. The clay (Lab. No. 2272) is of red and yellow color, very smooth and plastic, but in places may be quite gritty due to the presence of chert fragments derived from the limestone. The water of plasticity is 33 per cent, and the air shrinkage 7 per cent. In firing it gave an excellent brick at Cone 05, although the color is not very deep and the absorption somewhat high, due partly to the low fire shrinkage. Thus at Cone 010 the fire shrinkage was 0 per cent, with an absorption of 22.5 per cent, while at Cone 05 these values were 1.3 and 20.3 per cent, respectively. Only hand-molded brick have been made at this plant.

At another point $1\frac{1}{4}$ miles west of the city (Field No. 23) a small yard has been utilizing the upper 3 feet of gray and brown, somewhat sandy residual clay (Lab. No. 2273). This is somewhat similar to the preceding, but burns a little denser.

The clay required 29 per cent of water for mixing, and had 6.7 per cent air shrinkage. At both Cones 010 and 05 the fire shrinkage was zero, the absorption at the former cone being 19.5 per cent, and at the latter 18.2 per cent. At Cone 1 the fire shrinkage is 4 per cent. The clay does not give a very hard brick at Cone 010, but makes a good one at Cone 05.

ROCKBRIDGE COUNTY.

Buena Vista—Lexington area.—The Cambro-Ordovician rocks underlie a broad area in Rockbridge County, but the country is rather hilly, and hence the deposits, if worked, should lie as near to the railroad as possible. The Norfolk and Western Railroad traverses the eastern edge of the belt, and the Baltimore and Ohio Railroad the center as far as Lexington. The Chesapeake and Ohio Railroad extends eastward from Lexington to the eastern edge of the county and parallels the Norfolk and Western line in a general southwesterly direction.

There are in this county two limestone formations of some importance, namely, the Liberty Hall and the Natural Bridge. The former, although thin bedded and argillaceous, does not seem, on weathering, to yield as plastic a clay as the latter, nor were the deposits as heavy as those derived from the Natural Bridge formation.

Some of the shaly limestone (Lab. No. 2159), as exposed in the second railroad cut north of Fairfield, was tried, but found to have practically no plasticity even when ground very fine.

The Liberty Hall limestone area was crossed in two sections between Buena Vista and Lexington, but few deposits of residual clay derived from it were noticed. One was located 2 miles east of Lexington (Field No. 32), and, while the locality was not favorable for a brick plant, a sample was tested because it afforded a good opportunity to obtain some residual clay from this formation.

The clay (Lab. No. 2157) collected from this deposit worked up with 25 per cent of water and showed good plasticity. Its air shrinkage was 6.6 per cent, and average tensile strength 129 pounds per square inch.

The soft-mud bricklets gave the following results on firing:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	1	18.4
05	1	14.8
03	3	8.9

Even at Cone 010 the clay burned steel hard and gave a good ring. It fired all right up to Cone 03, at which it showed a tendency to develop surface cracks. The clay fires red. It should make a good brick, and would probably work in a stiff-mud machine.

The Natural Bridge limestone underlies a much wider area, and lies nearer to the railroads than the Liberty Hall limestone. It also seems to yield more residual clay.

One good section of clay is exposed along the Norfolk and Western Railroad about two miles due north of Buena Vista (Field No. 33). It is yellow and brown, and very plastic. The physical properties of this material (Lab. No. 2155) were as follows:

Water of plasticity.....	28%
Plasticity	Very good
Tensile strength, lbs. per sq. inch.....	55
Air shrinkage.....	6.7

Fire tests:

Cone	Fire shrinkage	Absorption
010	0%	22.8%
05	0	25.4
03	3.4	23.4
1	3.0	17.0
3	3.6	17.0
5	3.6	16.2
7	3.6	16.0
9	3.6	15.5
Color after firing.....	Red	
Steel hard.....	Cone 010	

This clay shows a very uniform fire shrinkage from Cone 03 to 9, with little decrease in absorption. It could be used in common-brick manufacture, and, as there are several other cuts near-by, there may be considerable available clay in the area.

North of Buena Vista around Riverside the clay exposures are not as extensive. Residual clay is exposed between Buena Vista and Loch Laird, southwest of Loch Laird on the road to Mechanicsville, and southward from Mechanicsville to Buffalo Forge (Field No. 34). The extent of these deposits has not been tested. At Buffalo Forge the clay is derived from shaly limestone.

The Buffalo Forge clay (Lab. No. 2156), although smooth feeling and very plastic, is also very sticky. The air shrinkage is not over 7.4 per cent, but it cracks badly in drying. Moreover, at Cone 010 its absorption is 27.2 per cent, so that this type of material is not to be recommended for brick. On the east side of the river there is little show of residual clay.

At Midvale (Field No. 35), north of Buena Vista, residual clay is well exposed in the road cuts leading from White Creek. It is somewhat similar to that along the railroad 3 miles north of Buena Vista (Lab. No. 2158). It has good plasticity, works up with 21 per cent water, and has 6.6 per cent air shrinkage.

At Cone 010 the fire shrinkage is .3 per cent, and absorption 19.8 per cent, while at Cone 05 the fire shrinkage and absorption are, respectively, 1 and 19.6 per cent. The clay at Cone 05 gives a good, hard, red brick.

BOTETOURT COUNTY.

Nace.—Associated with the brown iron ores derived from the Cambro-Ordovician rocks there are often bodies of whitish or yellowish white clay, which are more refractory than the associated ferruginous ones that occur in greater abundance.

At the No. 4 mine of the Houston Iron Company (Field No. 44), 1 mile southeast of Nace, there is a considerable quantity of the ferruginous clay exposed in the abandoned ore pits. The associated clays, however, are rather unique, for scattered through the ferruginous clay are bodies of a red, yellow, and white mottled clay which is very dense, fine-grained, and exhibits a splintery fracture when dry. The ground color is the white, while the blotches in it are 2 or 3 feet across, and remind one of the mottled clays associated with some of the Alabama bauxite. This blotched material is referred to as fire clay.

Associated with the so-called fire clay in irregular masses is bauxite. It is very ferruginous, ranges from hard to soft, and grades into the surrounding clay. The pisolites may be as much as half an inch in diameter, are of varying abundance, and appear to be more numerous in the bottom than in the top of the cut. In some cases the iron oxide is uniformly distributed through the bauxite, while at other times it is more or less concentrated in the nodules.

The following series of tests gives the properties of the fire clay (No. 2306) and of the bauxite (No. 2304) :

	No. 2304	No. 2306
Water required	34	30
Plasticity	High	Good
Air shrinkage	3.3	3.0
Tensile strength	21	....
Cone 010		
Fire shrinkage	1.7	....
Absorption .....	....	....
Cone 05		
Fire shrinkage	2.7	....
Absorption	38.7	....
Cone 03		
Fire shrinkage	5.0	....
Absorption	34.8	....
Cone 1		
Fire shrinkage	6.0	4.3
Absorption	35.1	31.1
Cone 5		
Fire shrinkage .....	....	5.3
Absorption .....	....	27.3
Cone 9		
Fire shrinkage .....	....	10
Absorption .....	....	18.9
Color	Red	Buff

It will be seen from the above tests that both clays burn to a very porous body, and the fire clay in addition develops many fine cracks in the firing operation. It is also questionable whether they could be used alone, as they would require a clay of better bonding power to be mixed with them. There is not enough of either clay to warrant establishing a plant at the mine, and the main use for them would be as an ingredient of porous shapes of semi-refractory character.

Daleville.—This town lies about $1\frac{1}{2}$ miles west of the Norfolk and Western Railway. Just east of it (Field No. 45) there is a good exposure of a smooth, red residual clay derived from a hard, blue-gray lime-

stone. It has 33 per cent water of plasticity. The plasticity is good, and the air shrinkage 9 per cent. The clay (Lab. No. 2231) burns red and becomes steel hard at Cone 05, it also shows a strong increase in shrinkage between Cones 010 and 03, characteristic of many limestone residuals. Thus at Cone 010 the fire shrinkage is 1.3 per cent, and absorption 24.1 per cent, while at Cone 05 the fire shrinkage had increased to 9.3 per cent, and the absorption dropped to 9.6 per cent. The material is a good brick clay.

Cloverdale.—This town lies in the Cambro-Ordovician area, but the exposures near the railroad are chiefly shales and are referred to on page 56. Residual clay from limestone is seen $1\frac{1}{2}$ miles east of town.

Lynchburg or Grubb mines.—These mines lie at the end of a branch track about 2 miles northwest of Blue Ridge Springs (Field No. 47). The ore is surrounded by a reddish residual clay that is probably of no economic value, but scattered through it are pockets of white and bluish-white clay of very dense, fine texture, and having the luster of dull-glazed porcelain. Some of these pockets are as much as 10 to 15 feet in diameter, and the line of separation between the white and the red clay is quite sharp. Up to the present time no use has been found for this material which occurs in limited quantities.

A chemical analysis of it shows:

Chemical analysis of clay from Lynchburg mines, Botetourt County.

	Per cent
Silica (SiO_2)	43.18
Alumina (Al_2O_3)	39.21
Ferric oxide (Fe_2O_3)	.15
Magnesia (MgO)	Trace
Soda (Na_2O)	.08
Water (H_2O) below 108°C .	3.39
Water (H_2O) above 108°C .	14.23
	100.24
Specific Gravity	2.46

While the material resembles the description of halloysite given by Dana, it has a somewhat higher alumina-silica ratio than does halloysite of the usually accepted composition.

The ferruginous clay associated with the brown ore is very plastic, and naturally burns red. It has a curiously sound ring after firing at Cone 010 even though its absorption is 28.4 per cent. At Cone 05 it shows the high fire shrinkage of 10.3 per cent, while its absorption has dropped to 9.4 per cent.

ROANOKE COUNTY.

Hollins.—Residual clays from Cambro-Ordovician limestones are exposed in several cuts near the Norfolk and Western Railroad (Field No. 46). One long cut is located about an eighth of a mile west of Hollins station, and another is just east of the railroad.

In the railroad cut an eighth of a mile west of Hollins station the clay (Lab. No. 2236) is yellow and red, very plastic, but contains some chert fragments derived from the underlying limestone. It required 37 per cent of water to mix it, and the air shrinkage was 7.5 per cent.

At Cone 010 the fire shrinkage was zero per cent, and the absorption 24.1 per cent, which is higher than is desirable. At Cone 05 the fire shrinkage was 3.3 per cent, and the absorption 17.6 per cent. The clay was steel hard at Cone 05, and fired red. It could be used for common brick, but should be fired above Cone 010.

Salem.—In the Valley immediately southwest of Roanoke there is little good residual clay exposed, although at Salem some is being worked from a low-lying deposit in the Valley. Here it occurs in a low-lying ridge just north of the wagon road, and about 2 miles southwest of the town (Field No. 56).

The clay is plastic, less than 15 feet thick where exposed, is underlain by limestone, and capped by stream gravels and sand. It is not used alone, but is mixed with clay from a near-by flood-plain deposit. In the bank of residual material there is both red and yellow clay, but the former is claimed to be too sticky for use. The mixture of clays is employed for the manufacture of soft-mud brick.

Southwest of Salem the Valley narrows, the slopes become steep, and there are few favorable locations for clay-working plants until the summit at Christiansburg is reached.

MONTGOMERY COUNTY.

Christiansburg-Blacksburg area.—From Christiansburg to Blacksburg the country, except for a small area around Merrimac, is underlain by Cambro-Ordovician limestone, which at many places shows banks of residual clay derived by weathering. It is all plastic and red burning. There are also scattered deposits in the area south of Christiansburg, but they lie too remote from the railroad to be worth working.

Radford.—One mile southwest of Radford (Field No. 62) and just southeast of the blast furnace is the yard of the Radford Brick Works, which was idle at the time of our visit. The clay is probably residual from

limestone. It is red and yellow, with fair plasticity, and sometimes contains gravel in its upper portion. The clay (Lab. No. 2116) worked up with 38 per cent of water, and had an air shrinkage of 8.5 per cent. Its tensile strength is 99 pounds per square inch, which is higher than most of the residual clays. The material fires red, but yields a very porous brick, although one with a good ring.

The fire shrinkage at Cone 010 is zero, with 33 per cent absorption, while at Cone 05 the fire shrinkage is .6 per cent, with 22.7 per cent absorption. This material has been used for common brick, and was molded on a stiff-mud machine. The chief objection to it is its high absorption.

WYTHE COUNTY.

Ivanhoe-Austinville area.—The Cambro-Ordovician limestones in the vicinity of Ivanhoe and Austinville have been weathered to residual clay, much of which has been worked over for the brown iron ore which it contains, and a little of which has also been excavated for recovering the oxidized zinc ores. (See Plate III, B.) The iron-ore pits lie mainly southwest and northeast of Ivanhoe, while the zinc-ore operations have been carried on chiefly near Austinville.

In the ore pits near Ivanhoe the clay seems to be mostly of a ferruginous character, but, east and northeast of Ivanhoe, the old ore pits often show pockets of white and yellowish-white clay surrounded by the iron-stained material. Considerable interest has been shown in these light-colored clays, and hence they were looked into somewhat carefully, but at no place did we find indications of any individual deposit of large size. It is possible, however, that some small factory making special shapes, like stove brick, could obtain enough material from the different pits to keep it running for some time. Some of them could also be used in sagger manufacture.

We give below a list of the localities examined together with a few preliminary tests that were made on a number of samples collected:

1. Locality, three-quarters of a mile northwest of Ivanhoe station (Field No. 107), on Painter farm. Residual clay from limestone. Clay (Lab. No. 2192), smooth; water required, 26 per cent; plasticity, high; air shrinkage, 8 per cent; Cone 010: fire shrinkage, 3 per cent, absorption, 9.31 per cent; Cone 05: fire shrinkage, 8.6 per cent, absorption, 6.40 per cent; color after firing, red; steel hard at 010. A good brick clay. Residual clay from iron-ore pits, 1 mile west of Ivanhoe station. Clay (Lab. No. 2196), dark red, smooth, very plastic; water required, 35 per

cent; air shrinkage, 5.2 per cent; Cone 010: fire shrinkage, 4 per cent, absorption, 30.7 per cent; Cone 05: fire shrinkage, 12 per cent, absorption, 15 per cent; nearly steel hard at Cone 010; color after firing, red. Can be used for brick, but total shrinkage a little high.

2. Bailey Crockett mine (Field No. 69), 2 miles southeast of Ivanhoe (Plate VI, A). In the irregular open cut of the abandoned mine there are pockets of white clay with yellow streaks. The quantity is uncertain.

The clay (Lab. No. 2112) is smooth and very plastic; water required, 35 per cent; air shrinkage, 4.7 per cent; Cone 010: too soft and porous; Cone 05: fire shrinkage, 1 per cent, absorption, 22.5 per cent; brick steel hard; Cone 03: fire shrinkage, 7.4 per cent, absorption, 11 per cent; color, cream. The clay is probably semi-refractory. Might work for stove brick or saggars, if there is a demand for it. Would hardly pay to work it alone.

3. Gregory Mine, 1 mile northeast of preceding locality (Field No. 70). Here the long narrow cut shows pockets of white clay streaked with yellow and red, but it differs considerably from the preceding clay in its firing qualities. The material (Lab. No. 2111) is smooth and gave the following results on testing:

Plasticity	Fair
Water of plasticity	33%
Air shrinkage	5.4%

Fire tests:

Cone	Fire shrinkage	Absorption
	<i>Per cent</i>	<i>Per cent</i>
010	3	24.2
05	6.7	11.7
03	11.3	2.43
1	13.1	1.50
Color after firing	Buff	
Steel hard	Cone 05	

The clay is of doubtful value, as its fire shrinkage is too high.

4. Austinville, road cut 1 mile south of station (Field No. 71), showing red residual clay from limestone, forming bank about 100 feet long and 15 feet high. It (Lab. No. 2110) is of red color, smooth, and worked up with 47 per cent of water to a mass of excellent plasticity. The air shrinkage is 9.9 per cent, but this is probably a little high. It worked fairly well in a stiff-mud machine, but in burning it behaved similar to some other limestone residual clays, showing a greatly increased shrinkage above Cone 010. This is shown in the following figures:

Cone	Fire shrinkage	Absorption
	<i>Per cent</i>	<i>Per cent</i>
010	1.6	27.5
05	10	10.5
03	12	3.93

The clay fires red, is nearly steel hard at Cone 010, and could be used for brick, but shrinks too much if fired much above Cone 010.

5. The red-brown clay (Lab. No. 2127) from the open pits of the old zinc-ore workings behaved somewhat similarly in firing and in its other tests, as can be seen from the following: Plasticity, high; water required, 40 per cent; air shrinkage, 8.6 per cent; Cone 010: fire shrinkage, 2.4 per cent, absorption, 22.6 per cent; Cone 05: fire shrinkage, 10.4 per cent, absorption, 16.5 per cent. Clay steel hard at Cone 010, and color after firing, red.

Wytheville.—There is not very much residual clay from limestone around Wytheville; since, from the hilly nature of the country, much of it has been removed by erosion.

The clay exposed about $1\frac{1}{2}$ miles southeast of Wytheville (Field No. 72) indicates the nature of the material occurring in this area so far as appearance and plasticity are concerned, but it differs from many of the other residual clays overlying the Cambro-Ordovician limestones, because of its higher shrinkage and lower absorption at Cone 010. A summary of its physical properties (Lab. No. 2147) is as follows: Plasticity, high; water required for mixing, 30 per cent; air shrinkage, 6.4 per cent; Cone 010: fire shrinkage, 6.3 per cent, absorption, 14.6 per cent; Cone 05: fire shrinkage 9.6 per cent, absorption, 11.0 per cent; color after burning, red; steel hard at Cone 010.

There is nothing in the appearance of the raw material to indicate that it would burn differently from many other similarly appearing residual clays. It should make a good brick at a low cone.

Another sample from a deposit 3 miles southeast of Wytheville (Field No. 113) had the following properties: Water of plasticity, 30 per cent; plasticity, high; air shrinkage, 3.4 per cent; color after firing, buff; steel hard at Cone 05. At Cone 010: fire shrinkage, zero per cent, and absorption, 12.7 per cent. At Cone 05: fire shrinkage, 7 per cent, and absorption, 4 per cent.

From Wytheville to Marion the railroad follows the limestone belt, and the cuts expose residual clay. Some of these may be noted, although the extent of the deposits is not known.

Rural Retreat.—Residual clay from limestone can be seen in the railroad cut one-half mile southwest of the station.

SMYTH COUNTY.

Groseclose.—The road cut just north of station shows shaly limestone, and there is also shale in cuts along the track, three-fourths of a mile northeast of the station, but neither of these is promising. Residual clay from limestone shows in the cut one mile northeast of station, and in another cut $1\frac{1}{2}$ miles from town.

Marion.—The limestone belt at Marion is about 4 miles wide, and a narrower belt lies about 5 miles south of Marion, being crossed by the Marion and Rye Valley Railroad to Fairwood. In the main belt, at least, there are several shale deposits, which are referred to on page 63.

Residual clay from the limestone can be seen at several points, but there are no large sections exposed. It has, however, been utilized on a small scale for the manufacture of brick. Several samples were collected and submitted to a partial series of tests. These are given below:

1. Locality, 1 mile north of Marion (Field No. 74), and just north of the fair grounds. This is a dark-brown residual clay (Lab. No. 2134), which tested out as follows: Plasticity, good; water required for mixing, 32 per cent; air shrinkage, 7.5 per cent; color after firing, red; steel hard at Cone 05, nearly so at Cone 010.

Cone	Fire shrinkage Per cent	Absorption Per cent
010	1.0	24.4
05	3.0	21.9
1	6.7	13.6

The clay makes a hard brick, but not a very dense one.

2. Locality, $1\frac{1}{4}$ miles northeast of Marion, brickyard of E. K. Coyner (Field No. 75). Clay (Lab. No. 2133), very plastic, yellow and brown, sometimes gray. Water required for mixing, 36 per cent; air shrinkage, 7.3 per cent; color after firing, red; steel hard at Cone 05. At Cone 010: fire shrinkage, 0.9 per cent, absorption, 22.4 per cent; Cone 05: fire shrinkage, 4.3 per cent, absorption, 19.9 per cent. The clay is being worked on a stiff-mud machine. Can be fired to a hard brick, but does not give a very dense one.

3. Locality, 2 miles south of Marion, brickyard of State Hospital (Field No. 76). Clay yellow and brown, with a little red and gray mottled. It (Lab. No. 2153) is quite plastic and smooth. Water required for mix-

ing, 34 per cent; air shrinkage, 8.2 per cent; color after firing, red; steel hard at Cone 010. At Cone 010: fire shrinkage, 1 per cent, absorption, 17.8 per cent; Cone 05: fire shrinkage, 3.7 per cent, absorption, 12.7 per cent.

This is a good brick clay, although it is claimed to overfire somewhat easily. It is being worked through a stiff-mud machine.

4. Currin Valley Mines, on Staley Creek, 6 miles southeast of Marion (Field No. 77). Here there is an old iron-manganese mine which was being reopened at the time of our visit. The clay in which the ore nodules lie is chiefly a ferruginous red and yellow material, but here and there in the deposit are some fairly large lenses of a yellow and whitish mottled clay, usually regarded as a fire clay, hence it was looked into in some detail.

There would be no profit in working the material alone, as it does not occur in sufficiently large masses, but it could be worked in connection with the ore; the masses of light-colored clay being separated out as they were encountered.

The material (Lab. No. 2321) is exceedingly smooth and plastic. It worked up with 39 per cent of water, and had 7.3 per cent air shrinkage. The average tensile strength was low, 24 pounds per square inch.

In firing it behaved as follows:

Cone	Fire shrinkage	Absorption
	<i>Per cent</i>	<i>Per cent</i>
010	.0	26.
05	3.7	21.9
1	6.7	14.
3	6.7	13.2
5	8.3	10.1

The clay fires red and becomes steel hard at Cone 05. The total shrinkage at Cone 5 is higher than desirable, but is not so at Cone 1, and in practice the air shrinkage would probably be lower than is given above. It is not a fire clay, but could be used for brick, although there is not a sufficient quantity for that purpose. It could probably be used for common earthenware, provided it was screened or washed first in order to free it of limonite nodules. The deposit outcrops on the lower slope of the valley side. Sandstone overlies it higher up the hill.

McMullin.—Residual clay from limestone is found at many points around McMullin, but none was sampled.

Chilhowie.—A fair-sized plant was formerly in operation north of Chilhowie, which manufactured a stiff-mud block that was somewhat extensively

sold for walks and station platforms, and many samples of which can be seen in the southwestern part of the State. The bricks have been referred to as vitrified, although only the surface was of that character.

The material used was obtained from the valley bottom adjoining the works and on the north side of the railway, and was probably residual material that had washed down into the valley bottom. The company is said to have suspended operations because the clay gave out.

Residual clay from limestone is available at several points in the vicinity of the town, notably on the southern edge, where a small sample was taken from the property of Q. A. Elders (Field No. 87). It is the usual red-burning brick clay.

WASHINGTON COUNTY.

Abingdon.—Residual clays from limestone are found around Abingdon, but are not used. It is reported that a buff-burning clay has been found near the town, similar to that obtained near Radford (p. 76) and Christiansburg (p. 74), but we were not able to verify the statement, as the test shafts from which it is said to have been taken had caved in.

Bristol.—The limestones around Bristol yield residual clays, which have been used to a small extent for making common brick, but they have strong competition with shale brick shipped from Tennessee.

SUMMARY OF PHYSICAL TESTS OF LIMESTONE RESIDUAL CLAYS.

In the table p. 55 we have tabulated the tests made on many samples of residual clays from Cambro-Ordovician limestones distributed throughout the Great Valley province of the State. The tests are interesting because they show more or less variation in the limestone residual clays. All the samples, with one exception, fired to a red color. The water of plasticity varies from 22 to 47 per cent. The plasticity in the majority of clays is at least good, while in many it is high. The tensile strength of the few tested shows considerable range.

At Cone 010 the fire shrinkage of practically all the clay samples tested is very low, and the absorption rather high, but at Cone 05 they show considerable variation in fire shrinkage and absorption. Many, however, give a good brick even at Cone 010.

They are not clays of the vitrifying type, but are to be regarded as good brick clays.

SHALY MEMBERS OF THE NATURAL BRIDGE LIMESTONE.

At several localities there occur within the area underlain by the Natural Bridge limestone, some strong beds of shale, the most accessible



(A) Residual clay at Bailey Crockett mine, 2 miles southeast of Ivanhoe, Wythe County.



(B) Weathered shale in Natural Bridge limestone formation, near Fin-castle, Botetourt County.



(A) Shale pit at Webster, Botetourt County.



(B) Fresh Cambro-Ordovician shale, same locality as (A).

Physical tests of residual clays from Cambro-Ordovician limestones.

Laboratory Number	Field Number	Locality	Water plasticity		Plasticity	Tensile strength	Cone 010		Cone 05		Cone 03	Cone 1	Cone 5	Cone 9	Color
			Shrinkage	Air shrinkage			Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	
2217	3	Berryville, 3 m. s. e.	34.0	7.9	Good	....	0.0	21.00	6.4	7.4	....	....	....	....	Red
2218	3	Berryville, 3 m. s. e.	20.0	7.2	Good	....	.3	20.2	....	....	....	....	....	....	Red
2219	4	Riverton	27.0	7.3	Good	....	.0	17.4	.7	15.0	....	....	....	....	Red
2221	10	Elkton	22.0	5.2	Fair	....	.3	17.0	.3	17.0	....	....	....	....	Red
2220	5	Strasburg	26.0	6.7	Excellent	....	.0	18.6	2.2	12.4	....	....	....	....	Red
2223	11	Harrisonburg, top clay	27.3	5.3	Excellent	....	.3	21.2	.3	22.2	....	....	....	....	Red
2222	11	Harrisonburg, bottom clay	25.0	8.2	Excellent	....	.7	15.7	4.0	10.7	....	....	....	....	Red
2224	12	Harrisonburg	25.0	8.3	Good	....	.3	23.6	6.3	18.0	....	....	....	....	Red
2225	13	Daxton	29.0	7.7	Excellent	247.0	.0	20.8	4.0	10.8	....	....	....	....	Red
2135	..	Stuart's Draft, 2 m. n.	27.0	7.7	Excellent	....	6.4	9.9	8.7	6.89	....	....	....	....	Red
2137	..	Stuart's Draft, 2 m. n.	27.0	7.4	Excellent	....	3.4	19.7	9.0	7.78	....	....	....	....	Red
2272	23	Staunton	23.0	7.0	Excellent	....	.0	22.5	1.3	20.3	....	....	....	....	Red
2273	23	Staunton	29.0	6.7	Good	....	.0	19.5	.0	18.2	....	4.0	....	....	Red
2157	32	Lexington, 2 m. e.	25.0	6.6	Good	129.0	1.0	18.4	1.0	14.8	....	....	....	....	Red
2158	23	Buena Vista, 2 m. n.	28.0	6.7	Good	55.0	.0	22.8	.0	15.8	....	....	....	....	Red
2158	35	Midvale	21.0	6.6	Good	....	.3	19.8	1.0	19.6	....	....	....	....	Red
2231	45	Daleville	33.0	....	Good	....	1.3	24.1	9.3	9.6	....	....	....	....	Red
2236	46	Hollins	37.0	7.5	High	....	.0	24.1	3.3	17.6	....	....	....	....	Red
2176	62	Radford	38.0	8.5	Good	99.0	.0	33.0	.6	22.7	....	....	....	....	Red
2192	107	Ivanhoe	26.0	....	High	....	3.0	9.31	8.6	6.4	....	....	....	....	Red
2196	107	Ivanhoe	35.0	5.2	High	....	4.0	30.2	12.0	15.0	....	....	....	....	Red
2112	69	Ivanhoe	35.0	4.7	High	....	Soft	1.0	1.00	22.5	....	....	....	....	Cream
2110	71	Austinville	17.0	9.9	High	....	1.6	27.5	10.0	10.5	....	....	....	....	Red
2147	72	Wytheville	30.0	6.4	High	....	6.3	14.6	9.6	11.0	....	....	....	....	Red
2131	74	Marion	32.0	7.5	Good	....	1.0	24.4	3.0	21.9	....	....	....	....	Red
2133	75	Marion	36.0	7.3	Good	....	.9	22.4	4.3	19.9	....	....	....	....	Red
2133	76	Marion	34.0	8.2	Good	....	1.0	17.8	3.7	12.7	....	....	....	....	Red
2321	77	Marion	39.0	24.0	High	....	.0	26.0	3.7	21.9	....	6.7	13.2	8.3	Red
											6.7	14.0		10.1	

*Cone 9, 3.6 fire shrinkage, 15.5 absorption.

being those near Cloverdale station in Botetourt County. Another interesting occurrence is that near Webster in the same county.

These shales do not work up well in their fresh condition, but weather to a very plastic clay, and even a slight amount of alteration sometimes imparts a very fair amount of plastic qualities to them. It is, therefore, of the highest importance to determine whether the material outcropping is fresh or weathered, and, if the latter, how deep below the surface the weathering extends; also, whether the depth of weathering is uniform.

BOTETOURT COUNTY.

Buchanan.—The Cambro-Ordovician limestones extend some distance west and northwest from Buchanan, and are crossed by the Chesapeake and Ohio Railway, but there are not many visible exposures of residual clay. A few were found in searching over this area and their characteristics may be noted.

About two miles slightly north of west from the Buchanan bridge and along the Springwood road (Field No. 50), there is residual clay derived from a shaly limestone. It is quite sticky and plastic, but the fresh rock is of no value for clay products. Similar clay shows in small cuts one mile northeast of Springwood, while a fourth of a mile to the northwest the bedrock, which is of a flaky or shaly character, appears. This same flaky rock shows across James River, one-half to three-fourths of a mile, and also $1\frac{1}{4}$ miles southwest of Springwood. In its fresh condition the shale yields very little plasticity on grinding, but at Cone 010 it burns to a whitish porous mass.

Fincastle.—Along the road from Lithia to Fincastle, and for a distance of two or three miles west from Looney's Mill Creek (Field No. 49), there is an abundance of residual clay from limestone. If it were used for brick manufacture the product would have to be hauled several miles to the railroad at Lithia. This clay, however, gives way to a shale about one mile east of Fincastle (Plate VI, B). The shale when fresh is dark-colored but turns grayish-yellow on weathering, and then disintegrates to a residual clay. It also contains some concretions. While in its fresh condition the shale (Lab. No. 2238) does not develop sufficient plasticity when ground to be workable, but the residual clay from it can be used, and some of the former could be mixed with the latter.

Cloverdale.—On the west side of the Norfolk and Western Railroad tracks, just north of Cloverdale station (Field No. 51), there is a long

exposure of shale and its overlying residual clay. The shale is grayish-brown, fine-grained, and not very hard, and in weathering breaks down first to splintery fragments.

The splintery shale was tried alone, but gave no promise of being workable, as it develops very little plasticity. The overlying residual clay is tough and plastic, and can be molded without any difficulty. Since, however, the clay is not of unlimited quantity, it would seem desirable if this deposit were worked to use a mixture of three-fourths clay and one-fourth shale. Such mixture (Lab. No. 2309) was accordingly tried.

It worked up with 31 per cent of water, and as a whole was highly plastic. The air shrinkage was 5.4 per cent, and the average tensile strength 35 pounds per square inch.

Firing tests gave the following results:

Cone	Fire shrinkage	Absorption
	<i>Per cent</i>	<i>Per cent</i>
010	0.	24.5
05	3.	19.3
1	5.4	12.5
5	8.7	2.0

The mixture was too porous at Cone 010, but at Cone 05 it was steel hard and made a good brick. It was practically vitrified at Cone 5. The material could be used for common brick, and it might work in a stiff-mud machine. There is also a possibility of using it for fireproofing.

As this shale and its residual clay occur east and northwest of Cloverdale, and also between Hollins and Roanoke, the area should be carefully examined before establishing a plant in order to find a location where there is the maximum amount of residual clay.

Webster.—This locality lies between Coyners and Blue Ridge Springs (Field No. 52), and is the site of an abandoned brick plant. The deposit worked is a calcareous shale, which has a steep southeasterly dip and lies in a hill on the northwest side of the railroad and several hundred feet from it.

One cut (Plate VII, A) has been made in the southern slope of the hill just back of the works. A track was also laid around the west side of the hill, and several small openings were made for taking out clay. As the beds strike northeast, the main cut follows along the strike of one set of beds, while the track laid around the west of the hill crosses the strike.

It is probable that the main cut on the south slope of the hill was so run because the beds it followed were more deeply weathered than some of the others.

So far as could be ascertained the perfectly fresh rock does not seem to lend itself to the manufacture of clay products, but a slight amount of weathering renders the material plastic.

On the west side of the hill several shaly beds are exposed, which have been partly altered, but not changed to clay (Plate VII, B). They strike N. 80° E. and dip 70° S. One of these beds is 10 feet thick, and another is 25 feet. They are about 10 feet apart. Here a pit about 25 feet deep and 40 feet wide was made. Two samples from this pit were put through a few preliminary tests.

One of these (Lab. No. 2308) represents the less-altered shale. It is quite smooth, brown to gray in color, and retains its original structure. It worked up with 22 per cent of water, had fair plasticity, and 3.6 per cent air shrinkage. At Cone 010 the fire shrinkage was zero per cent, absorption, 17 per cent, and bricklet rather poor. At Cone 05 the bricklet was hard, red, and showed 12.9 per cent absorption.

A sample of the thoroughly altered shale (Lab. No. 2307) is represented by a smooth, yellow shale, which with 30 per cent water developed good plasticity, the mixture so made having an air shrinkage of 4 per cent. At Cone 010 the body was too soft, but at Cone 05, with 6.3 per cent fire shrinkage, it gave a red brick that was nearly steel hard, and had 12.6 per cent absorption.

From these few preliminary tests it would seem that, while the slightly weathered shale alone could be used for brick, it would be desirable, as well as more practicable, to mix the top material in with it.

In the main cut the bottom is filled with wash, so the material is only exposed in the sides. Here we have partly weathered shale, capped by residual clay derived from it. (Plate VII, A).

The points to be considered here are how much difference is there between the clay and the slightly altered shale, and also whether a mixture of the two would produce very different results from either one alone. Another point on which some difference of opinion has been expressed was whether the clay would work in a stiff-mud machine.

For purposes of easy comparison, we give below: I, the slightly weathered shale; II, the residual clay; and III, a mixture of about three-fourths shale and one-fourth clay.

	I (Lab. No. 2254)	II (Lab. No. 2253)	III (Lab. No. 2375)
Water required, per cent.....	24	41	26
Plasticity	Moderate	Good	Fair
Tensile strength, lbs. per square inch	22	28	34
Air shrinkage	3.5	5	4

Cone 010			
Fire shrinkage	0	0	0
Absorption	20.5	31.7	20
Cone 05			
Fire shrinkage	4.7	11.6	5.3
Absorption	20.0	8.0	7.8
Cone 1			
Fire shrinkage	7	11	9.0
Absorption	1.3	0	0.8
Cone 3			
Fire shrinkage	Fused	10.0	9.0
Absorption		1.0	0.8
Cone 5	....	Nearly fused	....

The effect of the clay when added to the shale is well shown. Interesting is the fact that the tensile strength of the mixture is higher than that of the two materials alone, although this has been noted before.

All these bodies give a steel hard brick at Cone 05, and the material fires to a good red color. The mixture was tried in the stiff-mud machine and flowed smoothly through both the brick and hollow-brick dies.

There is no doubt that it could be used for making building brick and hollow brick, but there is some doubt as to whether it could be used for making vitrified brick.

Some years ago a rather complete brick-making plant was constructed at this locality, equipped with stiff-mud machines, drypans, repress, dry press, tunnel dryers, and down-draft kilns, but after running a short time it was abandoned, and at the time of our visit was idle.

Various reasons have been assigned for the failure of the plant, but there is a probability that too much hard shale was being used, and too little clay.

Excessive shrinkage of the product was claimed to be one fault, and, if the clay alone was used, this may have been a contributing factor.

The following is a chemical analysis of the shale clay from Webster:

Chemical analysis of clay from Webster, Botetourt County.

	<i>Per cent</i>
Silica (SiO_2)	51.08
Alumina (Al_2O_3)	22.05
Ferric oxide (Fe_2O_3)	10.43
Lime (CaO)	None
Magnesia (MgO)	2.28
Potash (K_2O)	5.92
Soda (Na_2O)	.20
Loss on ignition	7.36
	99.32

The most remarkable feature of this analysis is the high percentage of potash, which one would hardly expect in a residual clay. A microscopic study of the material shows, however, that there is a considerable amount of unweathered shale in the sample, and that hydromica is present in abundance. The high content of total fluxes, 18.83 per cent, including the high potash content, probably accounts for its low fusibility.

Northeast of Webster there is not a little shale exposed along the road, but it is mostly hard or gritty, although in places it was seen to be overlain by shallow deposits of residual clay. On the southeast side of the valley along the base of Porters Mountain the rock is mostly limestone with some residual clay overlying it.

ROANOKE COUNTY.

Bonsack.—A tongue of the Cambro-Ordovician formations extends northeastward from Roanoke up the valley of Glade Creek. The exposed rocks are chiefly shales and shaly limestones, lying mostly on the northwest side of the Norfolk and Western Railway.

Around Bonsack in particular there are exposures of residual clay derived from shales, but none of the sections is very deep, and time was not available to make borings. However, small samples were carefully taken at several different points, and they may be regarded as representing the fully weathered shale.

One of these was a fourth of a mile west of Bonsack (Field No. 57), and north of the road leading from Bonsack to Cloverdale. It is a yellow and red, smooth, plastic clay. No prediction can be made regarding the quantity of it.

The material (Lab. No. 2229) works up with 40 per cent of water, and had an air shrinkage of 9.1 per cent. This is probably high, and it could be molded with less water, which would reduce the air shrinkage.

At Cone 010 the fire shrinkage was zero, and the absorption 28.1 per cent, while at Cone 05 the fire shrinkage and absorption were 4.4 and 19.6 per cent, respectively. The clay burns red and is steel hard at Cone 05. Its absorption is a little high, but the material could be used for common brick.

Following up the Cloverdale road, the shales outcrop to the southeast of the Cambrian rocks, but are not promising. If we cross the Cambrian formation to the northwest side, the shale rock is there weathered to residual clay similar to that described above.

East of Bonsacks, about a fourth of a mile, are numerous outcrops of shale, of a blue, red, and yellow color. They do not, however, grind up to a plastic mass. Where weathered to clay the material is very plastic, although there is not much of it exposed.

Still farther east, about three-fourths of a mile from Bonsacks, the shale is weathered to a yellow and gray, smooth clay of good plasticity (Lab. No. 2227), which burns red, but at no place were more than 6 feet of it exposed, although it may be deeper. It showed 40 per cent water of plasticity, and 8.6 per cent air shrinkage. The material at Cone 010 showed no fire shrinkage, and had a high absorption of 26.3 per cent. At Cone 05, however, it gave a good brick with 6.4 per cent fire shrinkage, and 14.3 per cent absorption.

WYTHE COUNTY.

Wytheville.—There is no shale close to Wytheville, but 4 miles due north of west from the station (Field No. 73) there is an abundance of greenish-gray shale that breaks up very fine on weathering. It strikes N. 60° E. and dips to the southeast. The material can be seen at times in sections 10 feet deep.

In spite of its unpromising appearance, the material (Lab. No. 2083), when ground to pass a 20-mesh sieve, works up with 19 per cent of water to a mass that is sufficiently plastic to mold, and has 3.5 per cent air shrinkage. It gives a red brick that is steel hard at Cone 05. The fire shrinkage at Cone 010 is 1.4 per cent, and absorption, 11 per cent, while at Cone 05 these values were, respectively, 2 and 9.20 per cent.

We have here then a material which gives a fairly dense body at a comparatively low cone, and differs considerably from most of the other shales found in the Cambro-Ordovician formations.

WASHINGTON COUNTY.

Chilhowie.—One-half mile north of Chilhowie (Field No. 87), on the Marvin Saunders' property, there is a considerable area of buff shale, with a low westerly dip. Exposures are few, but there is scattered float. At one point near the top of the slope a pit had been dug from which it was possible to obtain a sample.

The excavation was made about ten years ago to supply some material to the local brick plant. If the material is all like that obtained from the pit (Lab. No. 2328) it seems curious that more of it was not used. The tests are given as follows: Texture, fine-grained; plasticity after grinding

to pass 20 mesh, moderate; water required, 25 per cent; tensile strength, pounds per square inch, 74; air shrinkage, 3.6 per cent.

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0	22.7
05	0	23.3
1	0	16.8
3	0	Nearly viscous

The wet-molded bricklets gave a good body even at Cone 010, and a splendid product at Cone 1 as far as hardness was concerned. The fire shrinkage, as will be seen, is zero, but the absorption is a little higher than desirable. A small quantity of plastic clay would tone this shale up tremendously, and it could probably be worked in a stiff-mud machine. It is not adapted to pavers, but might make partition blocks, even if used alone. It burns red. The firing range is short, and this is an objection to the material. The shale after grinding can also be molded dry press, and the bricklets so made gave 25.2 per cent absorption at Cone 010, and 16.3 per cent at Cone 05, although it is not quite clear why the dry press should burn denser than the wet-molded bricklet at the same cone.

ATHENS SHALE.

The Athens shale formation is one of considerable thickness in southwestern Virginia, and outcrops so prominently in places as to attract far more attention than it deserves. The beds are often carbonaceous, gritty, and sometimes highly calcareous. None of the samples that were tested gave any encouragement to use them alone.

MONTGOMERY COUNTY.

Ellett.—One location of prominence is along the Virginian Railway east of Merrimac, the shales being exposed in a number of cuts from Ellett to Ironto (Field No. 109). There are also a number of exposures near Trinity Cross Roads on the road leading from Cambria station on the Norfolk and Western Railway. In this region the shales are not only hard, gritty, and carbonaceous, but may at times contain pyrite or other concretions as well. They seem to weather slowly, and when this happens form a tough brown residual clay.

Since a number of inquiries were made regarding the possibility of using them, and since one-half mile south of Ellett on the Virginian Railway there is a considerable area of residual clay derived from a shaly lime-

stone, a mixture was made up, consisting of three-fourths Athens shale ground to pass a 20-mesh sieve, and one-fourth residual clay from the Cambro-Ordovician limestone.

This mixture (Lab. No. 2379) gave a mass of good plasticity with 24 per cent water, and 4.4 per cent air shrinkage. It burned red, and gave a fair brick even at Cone 010. Two burning trials were made at somewhat widely separated cones. The first of these at Cone 010 had zero per cent fire shrinkage, and 18 per cent absorption; the second burned at Cone 2, had 2.4 per cent fire shrinkage, and 9.3 per cent absorption. Such a mixture could be used for brick manufacture, although it would be more desirable to select a better shale elsewhere.

The Athens shale is also exposed along the western base of Paris Mountain east of Blacksburg. There are several areas of it also in the vicinity of Bristol, as shown in Geologic Atlas Folio 59 of the United States Geological Survey.

SMYTH COUNTY.

Marion.—The Cambro-Ordovician formation carries several beds of shale, which are to be seen at different localities east, north, and west of Marion. These shales vary somewhat when fresh, but are usually dark gray and even carbonaceous, in fact in their unaltered condition they seem decidedly unpromising. They weather, however, to a very tough plastic clay, and at some localities as McMullin, 5 miles southwest of Marion (Field No. 78), these clays are well exposed. At times the shales develop sufficient plasticity to work even when they are slightly weathered, but no large deposits of this nature were observed.

In an effort to determine their commercial value for making clay products, samples were tried from several different localities in the area around Marion, and the results are given below:

1. Locality, one-third of a mile east of Marion station (Field No. 79) on Norfolk and Western Railway. A large cut giving a good section is shown in Fig. 4. The clay at the west end of the cut is similar to that at the State Hospital yard. The finely broken limestone is badly altered and

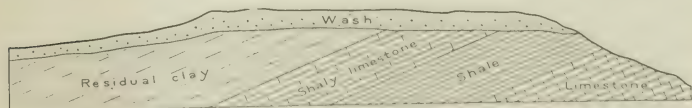


Fig. 4.—Section one-third of a mile east of Marion, Smyth County, Virginia.

might in part at least be used in a brick mixture. The shale (Lab. No. 2146) is black and flaky, but has probably been slightly altered, for it grinds up to a mass that with 15 per cent water develops fair plasticity.

Its air shrinkage and fire shrinkage at both Cones 010 and 05 are zero, and yet curiously enough even at the lower cone the clay burns nearly steel hard. At Cone 010 the absorption is 21.0 per cent, while at Cone 05 it is 19.1 per cent. The material could be mixed with the clay lying near-by. The question to be determined by more careful prospecting, of course, is whether there is enough of each available.

2. Locality, $1\frac{1}{2}$ miles northwest of Marion (Field No. 74). A dark-red shale, varying from massive to flaky, but in either case having a very clayey feel. The beds are more or less folded, but the exposure is about 100 x 9 feet. The physical properties (Lab. No. 2132) are:

	<i>Per cent</i>
Water of plasticity	20
Plasticity	Low
Tensile strength, lbs. per sq. inch.....	25
Air shrinkage	2

Fire tests:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	1.3	16.30
05	1.3	15.00
03	3.6	5.96
1	3.6	6.3
3	3.0	5.9
5	6.0	3.4
7	6.3	3.0
9	5.0	3.4
Color after firing		Red
Steel hard, Cone 05, nearly so at Cone 010		

The clay does not begin to overfire until Cone 9, and should work for products of low absorption. The chief objection is the low plasticity, but this could be remedied by adding a small quantity of more plastic clay. It can be molded dry press, and if fired at Cone 05 has a good ring and a fair color.

3. Locality, $2\frac{1}{2}$ miles southeast of Marion (Field No. 80). Hard, massive red shale. Does not develop enough plasticity to work.

4. Locality, east of Marion on road to Currin Valley Mines. Here there is more or less shale, evidently interbedded with the limestone. Most of it is hard and gritty. Just east of town, where the wagon road crosses the railroad, an excavation has been made in the shale for road material.

The fresh shale seen here (Lab. No. 2329) has no plasticity when ground and mixed with water, and the slightly weathered shale (Lab. No. 2322) develops such low plasticity that it is not to be recommended either.

5. Locality, McMullin, 5 miles southwest of Marion (Field No. 81). Black shale outcrops in the railroad cut about 100 yards east of McMullin, and also along the wagon road south of the track. In its fresh condition the shale is of no value whatever for making clay products.

At the west end of Copenhagen siding, a short distance east of McMullin, the shale is covered by 6 to 10 feet of very plastic residual clay. The material does not show in the railroad cut, which is in limestone, but, about 100 feet south of the track, the shale is found overlying the limestone and covered by clay. No plant has been established at this locality, but the brick works, formerly operating at Chilhowie, obtained some clay from here. Two sets of tests were made, (I) of the clay alone (Lab. No. 2331), and (II) of a mixture of three-fourths shale and one-fourth residual clay from it (Lab. No. 2373). The results of these are given below:

	I (Lab. No. 2331)	II Lab. No. 2373
Plasticity	High	Good
Water required	29%	23%
Average tensile strength, lbs. per sq. inch.....	46	35
Air shrinkage	4.2	4.3
Cone 010		
Fire shrinkage	0	0
Absorption	23.2	19.7
Cone 05		
Fire shrinkage	5.3	4.3
Absorption	11.8	9.6
Cone 03		
Fire shrinkage	7.0	4.4
Absorption	5.6	9.2
Cone 1		
Fire shrinkage	9.0	7.0
Absorption	2.0	5.3
Cone 3 .....	....	Viscous
Color	Red	Red
Steel hard	05	05

The clay alone makes a fair common brick at Cone 010, and an excellent one at Cone 05. The mixture gives a denser brick, and one that is good and hard, as well as of low absorption at Cone 03. It could probably be worked through a stiff-mud machine and used for hollow blocks, but is not recommended for paving brick.

SUMMARY OF PHYSICAL TESTS OF CAMBRO-ORDOVICIAN SHALES.

The materials, the tests of which are tabulated on p. 67, represent fresh shale in some cases, in others somewhat weathered rock. Nearly all of them show low tensile strength and low air shrinkage. The fire shrinkage at Cone 010 is in all cases low, and absorption usually high, but most of them at Cone 05 show a considerable decrease in absorption, with a good hard body. Several of them fuse at a low cone.

ORDOVICIAN SHALES.

The Ordovician formation carries some important and extensive shale deposits which extend from north to south across the State, usually within the Great Valley. In the upper half of the State these beds are known as the Martinsburg shale, while in the southwestern portion they are referred to as the Sevier shale. Their distribution is shown on the geologic map of Virginia issued by the Virginia Geological Survey in 1916. From this we see that they enter Virginia in the northeastern corner of Frederick County. The belt then passes southwestward, increasing slightly in width until west of Riverton it has a width of about 7 miles. Here it splits, the two portions passing around Massanutten Mountain, and the western one lying east of Woodstock. The two branches join just north of the line of the railroad connecting Harrisonburg and Elkton, and continue as a belt 5 to 6 miles wide, narrowing a short distance north of Greenville, Augusta County.

MARTINSBURG SHALE.

The Martinsburg shales, when fresh, are fine-grained, usually calcareous, and dark-drab to black in color. When weathered they become yellow or brown, and break down to a very plastic clay. The fresh shales do not slake down easily, and even if finely ground develop little plasticity; in fact, so far as our observations go, they are not suitable for brick manufacture. A comparatively slight amount of weathering, however, produces a noticeable improvement in their plasticity and general working qualities. Indeed it is possible to mix some of the fresh shale with the residual clay derived from it and get good results.

In the absence of deep cuts or borings it is, of course, impossible to tell how deep the shales have been weathered in different localities, but the ease with which they do seem to weather leads to the hope that sufficient plastic material for brick making could be found at not a few localities in the Shenandoah Valley from Staunton northward.

Physical tests of Cambro-Ordovician shales in western Virginia.

Laboratory Number	Field Number	Locality	Water plasticity	Plasticity	Tensile strength	Air shrinkage	Cone 010		Cone 05		Cone 03		Cone 1		Cone 5		Cone 9		Color
							Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption			
2227	48	Lithia	18.0	Fair	25.0	3.0	.0	....	2.0	8.6	....	....	7.0	5.0	5.0	6.7	Overfired	Red	
2309	51	Cloverdale, ¾ clay, ¼ shale	31.0	High	35.0	5.4	.0	24.5	3.0	19.3	3.0	....	5.4	12.5	....	....	8.7	2.0	....
2229	57	Bonsack	40.0	High	....	9.1	.0	28.1	4.4	19.6	....	....	....	....	....	....	....	....	....
2227	55	Bonsack	....	High	....	....	.0	26.3	6.4	14.3	....	....	....	....	....	....	....	....	....
2254	52	Webster, slightly wtd shale	24.0	Fair	22.0	3.5	.0	20.5	4.7	20.0	....	....	7.0	1.3	Fused	....	Nearly fused	....	....
2253	52	Webster, residual clay	41.0	Good	28.0	5.0	.0	31.7	11.6	8.0	....	....	11.0	.0	....	....	....	....	....
2275	52	Webster, clay shale mixture	26.0	Fair	34.0	4.0	.0	20.0	5.3	7.8	....	....	9.0	.8	9.0	.8	....	....	....
2083	73	Wytheville	19.0	Fair	....	3.5	1.4	11.0	2.0	9.2	....	....	....	....	....	Nearly vis- cous	....	....	....
2228	87	Chilhowie	25.0	Fair	74.0	3.6	.0	22.7	.0	23.3	....	....	1.0	16.8	Nearly vis- cous	....	....	....	....
2146	79	Marion	15.0	Fair	....	....	.0	21.0	.0	19.1	....	....	....	....	....	....	....	....	....
2132	74	Marion	20.0	Low	10.0	2.0	1.3	16.3	1.3	15.0	3.6	5.96	3.6	6.3	3.0	5.9	6.0	3.4*	....
2231	81	McMullin (clay)	20.0	High	46.0	4.2	.0	23.2	5.3	11.8	....	....	9.0	2.0	....	....	....	....	....
2273	81	McMullin, ¾ shale, ¼ clay	23.0	Good	35.0	4.3	.0	19.7	4.3	9.6	4.4	9.2	7.0	5.3	Viscous	....	....	....	....

*Cone 7, fire shrinkage 6.3%, absorption 3.0%; Cone 9, fire shrinkage 5.0%, absorption 3.4%.

The Martinsburg shale has been but little used in Virginia, although one yard is in operation at Staunton, and a small yard was working a number of years ago near Winchester.

Bricks, however, are being actively made from a mixture of the clay and shale at North Mountain north of Martinsburg, West Virginia, and also southeast of the town. This shale is referred to by Grimsley and Grout^a, who state that only the softer weathered portions of the material are employed at the brick works.

For purposes of comparison it may be interesting to give a few facts regarding the Martinsburg locality. Here the upper 10 to 30 feet of altered material is used. It is partly clay and partly altered shale (2282 and 2284). The unaltered shale (2283) is not usable alone. Sample 2283 is from a new yard near Martinsburg.

Partial tests of Martinsburg, W. Va., shale.

	2282 Residual clay	2284 Weathered Shale
Water of plasticity.....	26.5%	27.0%
Plasticity	High	Good
Air shrinkage	4.0%	3.4%
Cone 010		
Fire shrinkage	0.0%	0.0%
Absorption	13.3%	19.2%
Cone 05		
Fire shrinkage	3.6%	3.7%
Absorption	11.6%	8.6%
Color	Red	Red

The clay is ground in a dry pan, tempered in a pug-mill, and fired with producer gas. They have at times used nearly 50 per cent of the unaltered shale in the mixture, but this percentage produces black coring, bloating, and cracking. A few laboratory tests made on the Martinsburg materials as used show that they burn to a good hard body at Cone 05, but are too soft at Cone 010. They have not only been used for common brick but also for paving brick.

As the Martinsburg shale underlies a large area in the upper Shenandoah Valley, a number of localities were visited, and samples collected to gather some data regarding its possibilities.

^a Grimsley, G. P., W. Va. Geol. Survey, Vol. III: 202 pp., 1905.

FREDERICK COUNTY.

Winchester.—The shale belt lies east of Winchester, and material can be collected at a number of points although there are few deep cuts. Some of the exposures from which samples were obtained may be mentioned.

Two and three-quarter miles east of Winchester (Field No. 2), on a side road turning north from the Winchester-Berryville pike, the gray and brown altered shale is exposed in a long cut to a depth of not less than 6 feet. It is not as completely altered as that north of Martinsburg.

The material (Lab. No. 2286), although gritty, has good plasticity, working up with 22 per cent water. The air shrinkage, 3.8 per cent, is low. It burns to a moderately hard body at Cone 010, with zero per cent fire shrinkage, and 18.8 per cent absorption. At Cone 05 the fire shrinkage is 3 per cent, and absorption, 9.2 per cent, while the brick has a good red color and excellent ring. So far as these few tests go it is very similar to the Martinsburg, West Virginia, material.

The fresh shale can be seen about 50 yards east of the preceding locality. It is dark-gray and gritty, and so lean as to be unworkable. At most points along the Winchester-Berryville pike the shale where exposed is hard and gritty. Bricks were made a number of years ago by the Barr Brick Company, just north of Winchester, the material used being the altered shale.

Chambersville.—The Martinsburg shale forms a narrow belt, passing through Chambersville about 4 miles west of Winchester, but the shale shows a varying degree of alteration.

SHENANDOAH COUNTY.

Woodstock.—Woodstock is located on the western edge of the shale belt, and exposures of the weathered shale are observed at several points east and south of the town.

Thus $1\frac{1}{2}$ miles east of Woodstock, on the Fort Road (Field No. 6), the altered shale shows in the road cuts, although the sections are rarely over 3 feet deep. The material (Lab. No. 2292) is gray or yellowish-brown, soft and plastic, but retains the shaly structure.

It has a high plasticity when worked up with 27 per cent water, and an air shrinkage of 3.8 per cent. The air-dried bricks are not very solid, but the clay fires to a very good brick, which is of steel hardness at Cone 05, and good red color. At Cone 010 the fire shrinkage is zero, and absorption, 21.6 per cent, while at Cone 05 these are 3.7 per cent and 12.4 per cent, respectively. At Cone 3 the fire shrinkage was 7 per cent, and absorption

6.2 per cent. While these are only preliminary tests they indicate that the material ought to make a good brick and possibly also fire proofing.

One-half to one mile east of Woodstock the shale again outcrops and can be seen in cuts along the road, but it is not sufficiently altered to develop any plasticity when ground and mixed with water.

One-half mile south of Woodstock is J. S. Hoshour's brick yard (Field No. 7). The clay here is on a hillside above the creek, and while a part of it is undoubtedly residual, some of it is colluvial, although derived from the Martinsburg shale. This material (Lab. No. 2294), too, has good plasticity when worked up with 31 per cent water. The air shrinkage was 4.1 per cent. At Cone 010 the clay has zero per cent fire shrinkage, 18.3 per cent absorption, and a fair ring. At Cone 05 the fire shrinkage is 1.6 per cent, absorption, 14.5 per cent, and brick steel hard. The clay gives at both cones, a good red color. The bricks produced at this locality are hand made, and harder burning would improve them.

Strasburg.—The Martinsburg shale area lies south, east and northeast of Strasburg. The railroad to Riverton cuts through it.

East of Strasburg, $1\frac{1}{2}$ miles (Field No. 8), the weathered shale (Lab. No. 2289) is well exposed along the wagon road, and is of good plasticity with but little grit. Its water of plasticity, 18 per cent, is low, and so is the air shrinkage, which is but 2.6 per cent.

At Cone 010 the fire shrinkage is zero per cent, and absorption, 18.8 per cent, but the brick is not sufficiently hard to be recommended. Another sample burned at Cone 1 showed 8.6 per cent fire shrinkage, an absorption of only 4.1 per cent, and gave a good hard body. It would probably give a good product at Cone 05.

A good idea of both the weathered and unweathered shale can be obtained from a section in the cut (Plate VIII, A) of the Southern Railway, $2\frac{1}{4}$ miles southeast of Strasburg (Field No. 9). The fresh shale (Lab. No. 2290) is dark gray gritty material, which even when finely ground develops very little plasticity, and cannot be used alone on account of its leanness and carbonaceous character.

The weathered shale runs about 6 feet where exposed, and is typical of the residual clay derived from the shale, hence it was tested in detail, with the following results:

The clay (Lab. No. 2291) is of good plasticity, and requires 22 per cent of water for mixing. Its air shrinkage is 4.5 per cent, and average tensile strength when air dried, 86 pounds per square inch.

Firing tests of soft-mud bricklets gave the following results:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0	17.7
05	3	12.2
03	5.4	6.2
1	7.3	4.7
3	Viscosity beginning	

The clay fires red and is steel hard at Cone 05. A sample put through the stiff-mud machine flowed smoothly through the die.

A third lot was molded dry press. It did not give a sufficiently hard body at Cone 010, but at Cone 05 gave a good, steel-hard brick with 14.5 per cent absorption.

It is safe to say from these tests that the clay could be made into a dry press or plastic brick, and it could also be used probably for making fire proofing. There is some doubt as to whether it would make a good paving brick. These tests refer to the clay alone. There is no reason, however, why a limited amount of the underlying shale should not be mixed with the clay. In former years some of the residual clay near Strasburg was used for pottery manufacture.

ROCKINGHAM COUNTY.

Harrisonburg.—The Martinsburg shale forms a small area immediately west of Harrisonburg, a broader area lying several miles east, and a narrow tongue extending southwestward from this area and ending east of Harrisonburg. The country immediately east of Harrisonburg is underlain by residual clay derived from limestone.

Following the Chesapeake and Western Railway southeastward from Harrisonburg the shales appear between Keezletown and Montevideo. They weather easily, so most of the cuts show weathered material of a flaky nature, and sometimes sandy texture.

One of the best exposures, although not a very deep one, is one mile southeast of Penn Laird (Field No. 14). Here the shale consists of alternating clayey and sandy beds, with weathering extending to a depth of about 6 feet.

The weathered material here (Lab. No. 2280) shows fair plasticity and works up with 22 per cent water. Its air shrinkage is 3.1 per cent. At Cone 010 the fire shrinkage is zero per cent, and absorption, 18.0 per cent, but the brick is not hard enough. At Cone 05, however, the clay gives a good, steel-hard red brick of 1.3 per cent fire shrinkage, and 10.3 per cent absorption.

The fresh rock (Lab. No. 2281) shows the characteristic properties and does not make a good brick. In the shale area just west of Harrisonburg there may be weathered shale, but none was seen in the cuttings, and the fresh material (Lab. No. 2226) does not work satisfactorily.

AUGUSTA COUNTY.

Staunton.—This city lies very close to the shale belt, which is crossed by both wagon road and railroad going towards Basic City. Where fresh it shows the usual qualities that have already been mentioned, and which render it unfit for brick manufacture.

Such a deposit is well exposed in the Chesapeake and Ohio Railway cut 2 miles east of Staunton (Field No. 25). The material is carbonaceous, thinly laminated, and weathers light-colored on exposure, but does not slake down readily. A sample of it (Lab. No. 2267) even when finely ground did not develop much plasticity.

There are several other exposures east of Staunton, in which the rock shows varying degrees of weathering, so that a few data regarding them may be of value for purposes of comparison, although they do not represent extensive deposits.

Thus $2\frac{1}{2}$ miles east of Staunton on the main road to Basic there is a cut in the easterly dipping, hard bluish-black shale. This material (Lab. No. 2268) does not work satisfactorily.

Again 3 miles east of Staunton is another exposure, but the shale is very sandy.

About $2\frac{3}{4}$ miles east of town (Field No. 26), and just opposite the 218-mile post on the Chesapeake and Ohio Railway is a long low shale outcrop. This material (Lab. No. 2269) is slightly weathered, and works up with 18 per cent of water to a fairly plastic mass, with 3 per cent air shrinkage. Material weathered to the extent represented by this sample would make a fair brick, but it needs to be well oxidized in firing to bring out the red color. At Cone 010 the fire shrinkage is zero per cent, and absorption, 18 per cent, but the brick is not hard enough. At Cone 05 the fire shrinkage is 2 per cent, and absorption, 11 per cent. This latter cone gives a good product. Another outcrop sampled $2\frac{5}{8}$ miles east of town (Field No. 26) was slightly more weathered than the preceding one, and, although it required the same amount of water (18 per cent) to work it up, it had better plasticity. It made a good brick, but did not burn quite as dense. Thus at Cones 010 and 05 the fire shrinkage and absorption were, respectively 0 and 2.6 per cent, while the absorptions were, respectively, 23.7 and 14.5 per cent.

While there seems no doubt that the weathered Martinsburg shale can be used for brick, and probably for hollow brick or even drain-tile manufacture, we saw no sections of deeply weathered material, and if used it would probably be necessary to mix some of the unweathered shale with the clay. As stated above, this can be done.

The Standard Brick Company is operating a brick plant on the eastern edge of Staunton and utilizing the weathered Martinsburg shale. The bricks are molded on side cut, stiff-mud machines, dried in tunnel dryers, and fired in updraft kilns.

The clay derived from the shale by weathering is very plastic, but the shale when ground is granular and lean. Both fire to a red color, and while the clay alone could be used for brick manufacture it is very questionable whether the fresh shale alone would be of much value because of its low plasticity and carbonaceous character.

SEVIER SHALE.

This is the equivalent of the Martinsburg shale in southwestern Virginia. In its fresh condition it does not seem to be a very suitable material for the manufacture of clay products, nor is it always very accessible. A few localities where it occurs may be mentioned for the benefit of any who desire to look into it further.

Southwest of Pearisburg, Giles County, a belt of it crosses New River, to the north and south of Goodwins Ferry. Another belt lies just west of Clinch Mountain in Scott County.

There is a band of it on the southeast side of Moccasin Creek, to the northeast and southwest of Gate City, between Gate City and Moccasin Gap. The formation is reported, in places, to carry considerable yellow and blue shale.

Finally, a belt of the shale lies about two miles northwest of the valley of Holston River, along the southwest border of Russell County, and is not very accessible. Here it is described as a calcareous shale with thin beds of blue or red limestone, and passing upwards into a shale that is less calcareous but more sandy.

LEE COUNTY.

Pennington.—One-third mile north of here (Field No. 101) are two cuts about 150 feet long and 30 feet high, showing Ordovician shale, of which the lower half is partly weathered, and the upper half completely so. It represents the best material that we found in the Ordovician in Virginia.

The material (Lab. No. 2318) is brown, slightly gritty, but develops good plasticity when worked up with 26 per cent of water. The average tensile strength is 65 pounds per square inch, and the air shrinkage, 5 per cent.

The wet-molded bricklets yielded the following results:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	1	18
05	5.6	8.7
03	5	5.1
1	7	5.0
3	5	2.3
5	Beyond vitrification	Swelling

The shale fires red, and is nearly steel hard at Cone 010. The material could probably be run through a stiff-mud machine and used for hollow blocks, and possibly even paving brick.

It also yielded to dry pressing and gave a fair brick at 010 with 14.3 per cent absorption, and a good brick at 05 with only 9 per cent absorption.

None of the above samples represent fresh shale, all being at least slightly weathered. They all fire to a red color, and some fuse at a rather low cone. At Cone 05 all give a brick of moderate to low absorption. They can be used for brick and probably hollow brick, but are of doubtful value for vitrified wares.

ORDOVICIAN RESIDUAL CLAYS OF DOUBTFUL ORIGIN.

MONTGOMERY COUNTY.

Christiansburg.—Two miles east of Christiansburg (Field No. 63), on the north side of the wagon road, there is a long, low depression (Plate VIII, B) between limestone ridges, in which occurs a clay deposit of unique type. There is little doubt that this material is of residual character, and, since the surface material shows scattered angular fragments of sandstone, the clay is probably derived from the weathering of a clayey or feldspathic sandrock. It is sandy and of a gray color, while all the residual limestone clay of this region is strongly colored by iron oxide. Borings made in different parts of the deposit indicate a considerable quantity of the material, there being probably not less than 20 acres underlain by it. The clay (Lab. No. 2343), in spite of its grittiness, is very plastic, but took only 18 per cent of water to mix. The air shrinkage is 5 per cent, and the average tensile strength, 85 pounds per square inch.



(A) Cut in Martinsburg shale, $2\frac{1}{4}$ miles east of Strasburg, Shenandoah County.



(B) Area underlain by buff-burning residual clay, 2 miles east of Christiansburg, Montgomery County.



(A) Cut in Devonian shale, near old blast furnace at Goshen, Rockbridge County.



(B) Devonian shale at Longdale station, Alleghany County.

Physical tests of Martinsburg and Sevier shale in western Virginia.

Laboratory Number	Field Number	Locality	Water plasticity	Plasticity	Tensile strength	Air shrinkage	Cone 010			Cone 03			Cone 1			Cone 5			Cone 9			Color
							Fire shrinkage	Absorption	Fire shrinkage	Fire shrinkage	Absorption	Fire shrinkage	Fire shrinkage	Absorption	Fire shrinkage	Fire shrinkage	Absorption	Fire shrinkage	Absorption	Fire shrinkage	Absorption	
2286	2	Winchester	22.9	Good	....	3.8	.0	18.8	3.0	9.2	....	....	....	....	....	7.0	6.2	....	....	....	....	Red
2292	5	Woodstock	27.0	High	....	3.8	.0	21.6	3.7	12.4	....	....	....	....	....	....	....	....	....	....	....	Red
....	7	Woodstock	31.0	Good	....	4.1	.0	18.3	1.6	14.5	....	....	....	....	....	....	....	....	....	....	....	Red
2289	8	Strasburg	18.0	Good	....	2.6	.0	18.8	....	....	....	....	....	....	....	....	....	....	....	....	....	Red
2291	9	Strasburg	22.0	Good	86.0	4.5	.0	17.7	3.0	12.2	....	....	....	....	....	....	....	....	....	....	....	Red
2280	14	Harrisonburg	22.0	Fair	....	3.1	.0	18.0	1.3	10.3	....	....	....	....	....	....	....	....	....	....	....	Red
2318	101	Pennington	26.0	Good	65.0	5.0	1.0	18.0	5.6	8.7	....	5.0	5.1	7.0	....	5.0	2.3	....	Swelling	....	....	....

The following results were obtained on wet-molded bricklets:

Cone	Fire shrinkage	Absorption
	<i>Per cent</i>	<i>Per cent</i>
010	1.3	12.6
05	1.3	12.4
03	1.3	10.5
1	1.3	11.1
3	1.3	9.0
5	1.4	9.0
9	2.0	8.0
27	....	Fused

The clay fires buff and is steel hard at Cone 05. A sample was tried in the stiff-mud machine and flowed smoothly through the die.

The material is to be classed as a low-grade fire clay. Its interesting combination of qualities are its good plasticity, buff color after burning, low fire shrinkage, and low absorption. It could be utilized in the manufacture of buff-colored face brick, terra cotta, and low-grade fire brick.

The deposit lies not more than three-fourths of a mile from the railroad in an air line, and is well worth developing.

PULASKI COUNTY.

Radford.—About one mile southwest of Radford (Field No. 62), on the Lyell property, is an elongated shallow depression, in which a test shaft was sunk. After penetrating 5 to 6 feet of overburden the shaft penetrated a light-gray clay with yellow mottling for 20 feet. Below this there was a red clay that looked like a decomposed shale.

The surface material is a mantle of ferruginous clay with pebbles of quartz and sandstone. We are somewhat in doubt as to the origin of this clay on the Lyell property, and it is difficult to express an opinion from what can be seen in the test hole. The material occurs at practically the same level as that on the Nelson property (p. 112), but appears different in color and other properties.

The clay (Lab. No. 2326) has little grit, works up with 24 per cent of water, and develops high plasticity. Its air shrinkage is 7.3 per cent, and its average tensile strength is 80 pounds per square inch.

Burning tests of molded bricklets were as follows:

Cone	Fire shrinkage	Absorption
	<i>Per cent</i>	<i>Per cent</i>
010	0	21.5
05	2	16.3
1	6.3	4.8
3	6.0	5.0
5	7.4	2.7
9	8.3	1.3

The clay burns steel hard at Cone 05, and develops a fine buff-colored brick. It, too, should do well for face brick.

The buff-burning character of the clays from Christiansburg and Radford, together with their semi-refractory character, should soon find a use for them.

DEVONIAN SHALES AND RESIDUAL CLAYS.

The Devonian formation in western Virginia lies on the west side of the Valley region, and underlies an area of considerable extent, but much of it lies remote from lines of railway. Its distribution can be seen by reference to the geologic map of Virginia issued by the State Survey in 1916. Beginning at the northern boundary of the State and proceeding southward, no railway line crosses it until we reach the one running from Harrisonburg west to Stokesville. From a point a few miles west of Staunton, it is traversed by the Chesapeake and Ohio until it leaves the State. An arm of it is crossed by the same road between Clifton Forge and Eagle Mountain, and a branch southward from there to Newcastle, as well as one from Covington to Jourdan Mines.

In the extreme southwestern corner of the State, the Virginia and Southwestern Railway crosses the Devonian between Hilton and Moccasin Gap, and near Oreton; the Louisville and Nashville Railway southwest of Pennington; and the Norfolk and Western Railway near Richlands.

The Devonian formation in western Virginia exhibits on the whole a vast amount of shales, and also some sandstones, as well as residual clays. These shales were examined at many points, as the localities described and the tests quoted above will show and at a number of localities show promising qualities. The Devonian, therefore, is adapted to the manufacture of certain desirable grades of clay products.

The reason for the nonutilization of some of the shales is because in their fresh condition they are often too hard and gritty, as well as being so firmly cemented together that they fail to disintegrate in water, and even when finely ground develop little or no plasticity when mixed with water. Then, too, some of them are highly carbonaceous. But it is not always safe to pass judgment on a shale from its appearance, for some soft shales show few good workable qualities, while others of unpromising appearance prove most docile, and yield good results when molded.

While, however, the fresh shale is sometimes worthless for making clay products, a comparatively slight amount of weathering may produce a

marked change in the character of the material. The question to be determined, of course, is how deep the weathering has extended, and this can often be ascertained only by test pitting.

In addition to the shales there are also several deposits of residual clays, notably those of Frederick and Botetourt counties described below. The localities examined are arranged from north to south across the State.

FREDERICK COUNTY.

Whitish residual clay associated with Oriskany brown iron ore has been found on the northwest slope of Great North Mountain near Rock Enon Springs. The quantity is not known, but it is exposed in several test pits dug for iron ore.

Another deposit of whitish residual clay (Field No. 1), derived probably from Devonian shale, is known to occur on the southeast side of Great North Mountain, a short distance west of Mountain Falls. The material in its air dried condition is a white clay with yellowish mottlings, and rather indicates from its appearance that it might be almost white burning. The sample sent in for testing showed but little grit.

The physical properties are as follows:

Water of plasticity.....	20%
Plasticity	Good
Modulus of rupture, lbs. per square inch.....	80
Linear air shrinkage.....	7%

Fire tests:

Cone.	Fire shrinkage Per cent	Absorption Per cent	Color
1	2	7.6	Cream white
3	3	4.5	Buff
5	4.5	1.8	Buff
9	4	1.9	Buff

The clay is steel hard at Cone 1. The plasticity and fire shrinkage are satisfactory. The linear air shrinkage is normal, but the modulus of rupture is not very high. The material does not fire white enough to be used in any white ware body, but it could be used in the manufacture of stoneware.

ROCKBRIDGE COUNTY.

Goshen.—Just south of Goshen (Field No. 36) there is a small mound of shale which has been cut through by the railroad track that runs to the old furnace (Plate IX, A). It is dark gray, partly weathered, and quite free from sandstone, so that it may be taken as an example of what a small amount of weathering will do.

The shale (Lab. No. 2271), when ground to pass a 20-mesh sieve, worked up with 19 per cent of water to a mass of excellent plasticity, whose air shrinkage was 3 per cent. At Cone 010 the fire shrinkage was zero per cent, and absorption, 17.7 per cent, while at Cone 05 these were 1.3 and 11.4 per cent, respectively. The firing tests were as follows:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	0	17.7
05	1.3	11.4
1	2.0	8.0
3	4.6	4.7
5	4.0	4.6
7	3.0	3.1
9	0	2.3
Steel hard Cone 05		
Color after firing red, turning to buff.		

The shale begins to overfire above Cone 5, in so far as swelling is concerned, but should be adapted to the manufacture of structural clay products where a hard and fairly dense body is required.

There are other cuts of shale around Goshen, but those seen were all hard material, and besides they often contained too many sandstone layers for commercial purposes.

BATH COUNTY.

Millboro.—There are large cuts of Devonian shale to the southwest of Millboro along the line of the Chesapeake and Ohio Railway. The material, however, is hard and flint-like, as well as containing numerous sandstone layers.

We tried one sample (Lab. No. 2247) from a point an eighth of a mile southwest of Millboro Station (Field No. 28), but it is too low in plasticity to be workable.

AUGUSTA COUNTY.

North Mountain.—The Devonian shales which outcrop so abundantly along the Chesapeake & Ohio Railway between Goshen and Clifton Forge are usually black, gritty, and hard. At North Mountain station, however, there is a series of cuts along the railroad in which the shales are more or less weathered (Field No. 104). West of the station the shale contains numerous sandstone layers up to 4 inches in thickness, but east of the sta-

tion the sandstone layers are much less abundant. The faces of the cuts reach up to 25 feet in height, and they extend for a distance of probably two miles. The dip of the shale is variable, being southeast in places, northwest in others, and sometimes even vertical. This variation in dip showing local folding, is probably due to a neighboring fault.

The shale is yellow, gritty, and breaks up easily to rectangular and scaly lumps. It does not grind down very readily, and has moderate plasticity when worked up with water. Finer grinding would increase its plasticity somewhat and decrease its granularity.

The specimen tested showed 2 per cent linear air shrinkage, and a modulus of rupture of 50 lbs. per square inch. The clay fires to a red body of fair hardness even at cone 05, but shows a tendency to overfire at cone 1. It can be used in brick manufacture, but is of questionable value for any wares requiring a vitrified body.

Fordwick.—The Lehigh Portland Cement Company has opened a large shale quarry at Fordwick for using the shale at its cement plant (Field No. 21).

The shale is massive and dark gray when fresh, but upon weathering develops a platy fracture and becomes crumbly. Further weathering causes it to turn yellow and become much softer.

The following three partial analyses, supplied by the company, are of interest in showing the composition of (1) fresh shale, (2) slightly weathered shale, and (3) more advanced stage of weathered shale:

*Chemical analyses of fresh and weathered shales, Fordwick,
Augusta County*

	1	2	3
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Silica	51.80	54.88	60.34
Alumina	18.36	17.36	24.12
Ferric oxide	5.36	5.74	3.34
Lime	7.12	4.73	.36
Magnesia	2.00	1.89	1.41
Sulphur	2.20	2.76	.26

The effect of weathering is interesting and what might be expected. It results in a loss of ferric oxide, lime, magnesia, and sulphur. This results, of course, in a corresponding increase in the silica and alumina.

There is not enough of the weathered material to work it alone.

A sample of the fresh (Lab. No. 2276) and the slightly weathered (Lab. No. 2277) shale were both ground and mixed with water, but neither developed sufficient plasticity to work. It may be added that the slightly weathered piece had been lying on the pile exposed to the weather for seven or eight months.

A piece of weathered material (Lab. No. 2278) taken from the top of the cut, and exposed to the weather for a considerably longer time behaved quite differently.

This when ground to pass through a 20-mesh sieve and after mixing with 21 per cent of water developed good plasticity. Its air shrinkage was low, and it burned to a good red brick at Cone 05. The firing tests gave fire shrinkage at Cone 010, zero per cent, with 15.6 per cent absorption; and at Cone 05, fire shrinkage, 4.7 per cent, with 7.6 per cent absorption. If a large deposit of this nature were obtainable it would make a good brick proposition, and might even work for fire proofing.

ALLEGHANY COUNTY.

Longdale.—There is a great quantity of shale in this locality. Thus along the road from Clifton Forge to Longdale Station the rock exposed is nearly all hard gritty Devonian shale. At Longdale Station (Field No. 39) there is a large bank of shale (Plate IX, B) which is slightly weathered although we do not know how far in the weathering extends.

This shale (Lab. No. 2245), although somewhat coarse-grained even when ground to pass a 20-mesh sieve, worked up with 23 per cent of water to a mass of fair plasticity. Its air shrinkage was 3.9 per cent, and average tensile strength, 28 pounds per square inch. The material fires red, but required thorough oxidation to produce this color.

When fired at Cone 010 it is still too soft to make a good brick. Another sample fired at Cone 1 showed 6 per cent fire shrinkage, and 5.5 per cent absorption; a third, fired at Cone 3, and had 4.5 per cent absorption.

We were also able to dry press the material without much trouble, and a brick so made and fired at Cone 05 was steel hard, with 10.9 per cent absorption. The material collected from the bank could be used for brick.

In following up the mine railroad from Longdale Station the shale is seen in the limestone quarry resting directly on the limestone, without the Oriskany sandstone between the two, but it is too hard for use.

There are also additional cuts in shale at Longdale furnace and at Longdale mines. Where the shale is fresh it is hard, platy, black, and at

times contains concretions or even hard beds of sandstone. It breaks down readily to scaly fragments and these resist further attacks of the weathering agents for some time.

In places, however, the shale shows more advanced decay, and then becomes quite plastic, but it is always a question of how deep the weathering extends, and how much of the weathered material there is. There is, too, the added trouble that two samples of slightly weathered shale, which look and otherwise seem very similar, behave quite differently when treated in the laboratory. Thus we took one sample of slightly weathered shale from the railway cut at Longdale furnace (Field No. 40), but this material (Lab. No. 2260) had altogether too little plasticity to mold.

Another sample, appearing but little more weathered, was collected close to the Longdale mines and acted quite differently in the laboratory tests.

The sample of more weathered shale (Lab. No. 2259), when ground to 20 mesh, worked up with 25 per cent of water to a mass of very fair plasticity, whose air shrinkage was 3.2 per cent, and average tensile strength, 26 pounds per square inch.

The firing tests of the bricklets gave the following results:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0	26.5
05	3.6	20.3
1	7	5.5
2	7	6.2
3	8	3.9
5	6.7	3.8
7	5	2.8
9	4.3	2.4

This shale resembles in many respects the one tested from near Goshen (p. 79), but is a little fresher. It is also interesting to note that a slight amount of weathering appears to make quite a difference in the working properties of the material.

This type of shale should work well for the manufacture of red structural clay products where a body of low absorption is desired. The clay oxidizes slowly, burns red, and makes a good brick at Cone 03, although it might be burned a little lower. It might work in a stiff-mud machine, but would require thorough grinding and tempering.

Clifton Forge.—The shales around Clifton Forge are too hard and gritty for the manufacture of clay products, as are also those exposed in the cuts between Clifton Forge and Low Moor.



(A) Devonian shale, opposite limestone quarry, Low Moor, Alleghany County.



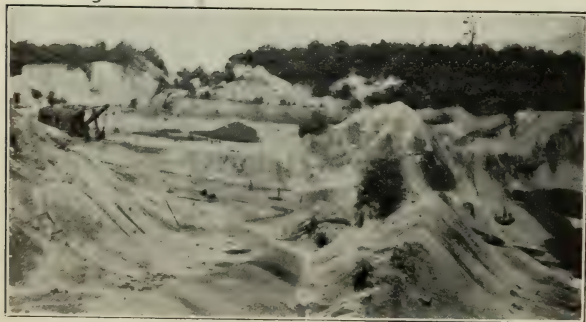
(B) Concretion in gritty carbonaceous shale, Low Moor, Alleghany County.



(A) White clay over brown ore at Lignite, Botetourt County.



(B) Near view of material shown in (A).



(C) Old brown-ore pit at Fenwick, Botetourt County.

Low Moor.—On the east side of the valley opposite the limestone quarry there is a good outcrop of shale (Plate X, A) along the wagon road (Field No. 41) which has been quarried for road material, and is slightly weathered. The material (Lab. No. 2240) is dark gray, and develops fair plasticity with 27 per cent of water. Its air shrinkage is 3 per cent, and average tensile strength, 26 pounds per square inch. At Cone 010 the fire shrinkage is zero per cent, but the brick is too soft. Another sample fired at Cone 1 showed 4 per cent fire shrinkage, and 13.1 per cent absorption; it was also steel hard. The shale of this nature could be made into brick, and fired even lower than Cone 1. It has a long oxidation period and burns red.

In the limestone quarry above mentioned the rock contains a number of solution channels, which are usually vertical, sometimes as much as 6 feet in width, and filled with a sticky clay, an analysis of which may show from 2 to 6 per cent zinc. The material has to be avoided in quarrying, and has no particular use.

Covington.—Following up the valley of Jackson River towards Hot Springs there are extensive outcroppings of Devonian shale, in fact an almost continuous section is to be seen along what is known as the Mountain Road leading up the east side of the valley. The shale is usually carbonaceous, gritty, and hard when fresh, but weathering often alters it to a marked degree. As illustrative of this we may take the properties of two samples collected along the road a short distance south of Falling Springs (Field No. 106). These represent slightly weathered shales, but we cannot say to what depth they have been altered. The following are partial tests of them:

	Lab. No. 2263	Lab. No. 2264
Water of plasticity	31%	31%
Plasticity	Excellent	Excellent
Air shrinkage	4.1	3.3
Cone 010		
Fire shrinkage	0	0
Absorption	28.7	24.9
Cone 05		
Fire shrinkage	3.3	2.3
Absorption	18.2	19.5
Cone 1		
Fire shrinkage	10.3	....
Absorption	5.0	....
Cone 3		
Fire shrinkage	11.7	....
Absorption	4.5	....

No. 2263 is nearly steel hard at Cone 010. It fires to a red color, and would work for brick and hollow tile. No. 2264 also fires to a good body of red color. It is similar to the preceding one (No. 2263).

If there is enough of the slightly weathered shale it could be quarried on the mountain side, and transported by wire-rope tram to a plant in the valley.

Clifton Forge to Eagle Rock.—There are numerous outcrops of Devonian shale along the wagon road between these two points, but none of it is very promising. The following deposits may be noted as a matter of record:

One mile south of Iron Gate. Shale contains too much hard rock.

One-half mile south of Lick Run. Shale hard and gritty.

East of Big Hill (Field No. 42). Large mass of shale (Lab. No. 2242) which is not very hard and weathers to platy fragments, but it does not give a plastic mass when ground up.

One and one-half miles north of Eagle Rock there is a large railway cut in shale, but the shale (Lab. No. 2243) does not make a good brick material.

Again one-fourth of a mile northeast of Gala station there is a hill of shale, but the shale (Lab. No. 2244) is too hard to mold well.

Shales of slightly better character outcrop in the railroad cuts of the Newcastle Branch of the Chesapeake & Ohio Railway south of Eagle Rock.

BOTETOURT COUNTY.

Lignite.—At this locality (Field No. 53) there are extensive mines of Oriskany brown iron ore that have been in operation for some years. The mines, owned by the Alleghany Ore and Iron Company, were opened first by a long cut, following the outcrop of the ore body. The ore has a footwall of limestone, and a hanging wall of Oriskany sandstone, while on top of the latter is the Devonian shale.

Where the cut has been made the shale is no longer fresh, but has weathered down to a whitish clay, whose thickness ranges from 5 to 10 feet, and extends quite persistently along the face of the excavation above the ore (Plate XI, A). The white clay passes upward into a reddish one, which appears in places, and is in turn capped by a mixture of dirt and angular rock fragments.

The white clay can be traced for about 300 feet along the face of the cut, but we are informed that it has been actually traced for a distance of several thousand feet beyond the cut.

A churn drill boring put down farther down the dip is said to have penetrated black shale, and then white clay, but the former does not appear in the face of the cut, unless it is represented by the red clay.

The white clay (Lab. No. 2344) is dense, not distinctly stratified, and in structure somewhat resembles the Dickinson clay at Buena Vista. Mr. Stull, the manager, states that in places the clay sometimes shows a microlitic structure, but does not show a composition resembling bauxite.

It works up with 35 per cent of water to a mass of good plasticity, which had 6.1 per cent air shrinkage.

The firing tests were as follows:

Cone	Fire shrinkage	Absorption
	<i>Per cent</i>	<i>Per cent</i>
05	5.2	11.
03	10.6	.3
1	10.5	0.
3	10.8	.2
5	11.3	0.
9	8.3	.5

The clay burns buff, but was gray at Cone 9. It was steel hard at Cone 05. This is a very interesting clay. In the first place it becomes practically non-absorbent at Cone 03 and remains so to Cone 5, above which the absorption increases slightly, due to overfiring. Similarly the shrinkage remains practically constant from Cone 03 to Cone 5, but decreases at 9. It may, therefore, be beyond vitrification at the last-named cone. The fire shrinkage is too high to permit its being used alone.

It may be summed up as a plastic, dense-burning clay. While it could be used for face brick, its properties would seem rather to class it as a stone-ware clay, and it should be brought to the attention of pottery manufacturers.

An analysis of this clay yielded:

Chemical analysis of white clay from Lignite, Botetourt County.

	<i>Per cent</i>
Silica (SiO_2)	59.17
Alumina (Al_2O_3)	24.26
Ferric oxide (Fe_2O_3)	4.62
Lime (CaO)	None
Magnesia (MgO)	1.06
Potash (K_2O)	4.94
Soda (Na_2O)	.27
Water (H_2O)	5.72

100.04

The red clay is quite different in its properties, and is not as desirable. It (Lab. No. 2377) develops very high plasticity when worked up with

34 per cent of water, has 7.3 per cent air shrinkage, and 90 pounds per square inch tensile strength. It burns red and becomes steel hard at Cone 010, but has an abnormally high fire shrinkage as the following tests will show:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	1.0	30.00
05	10.4	12.4
1	16.7	1.3
3	13.0	1.7

The fire shrinkage is altogether too high to permit this material being used alone. It seems to have reached its vitrifying point at Cone 1, for above that the shrinkage shows a decrease and the absorption a slight increase. It is possible that the clay might work in a mixture with the preceding white clay. If used alone it would not be safe to burn it above Cone 08.

Fenwick.—The ore mines at Fenwick (Field No. 54) are about one mile in an air line southwest from the mines at Lignite. Here, too, the ore is now obtained from underground workings, but there is a large open cut (Plate XI, C) from which the ore was formerly dug with a steam shovel.

In this abandoned cut there are large quantities of a soft, weathered, bluish shale, which is very smooth, and in places carbonaceous. Underlying it is sandstone showing a southwest dip. The shale is at least 25 feet thick, but is not continuous, for it may contain pockets of ore and sand rock.

On the west side of the pit is a mass of light-colored clay, about 15 x 7 feet in size, thought to be fire clay, and which grades into the blue material. The properties of these two clays are interesting.

The bluish weathered shale (Lab. No. 2258) works up with 27 per cent of water to a mass of high plasticity, whose air shrinkage is 3.7 per cent, and average tensile strength, 47 pounds per square inch.

One lot of the plastic material was molded into bricklets, with the following results:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0	23.6
05	4.4	12.1
03	5	4.7
1	10.4	0
3	10.0	0
5	10.0	0

The fire shrinkage and absorption are very similar to those shown by the white clay associated with the iron ore at Lignite (p. 84), in fact the two clays occupy similar stratigraphic positions, but differ in their color in the unfired state.

A second lot was tried in the stiff-mud machine, and worked very smoothly through the die.

A third lot was dry pressed, and this at Cone 05 was steel hard with 10.6 per cent absorption. The clay burns buff, but has evidently reached its vitrification point at Cone 1. It could be used for making dry-pressed brick, or also earthenware.

The so-called fire clay (Lab. No. 2261) develops high plasticity with 30 per cent of water. Its air shrinkage is 5.3 per cent, and average tensile strength, 40 pounds per square inch.

When tested in the stiff-mud machine it flowed from the die in a very smooth column and showed no tendency whatever to tear.

The molded bricklets gave the following results:

Cone	Fire shrinkage	Absorption
	<i>Per cent</i>	<i>Per cent</i>
05	4.3	13.9
1	6.0	0.18
3	6.6	0.5
5	10.4	0 0
9	8.3	0.0

The clay burns buff and is steel hard at Cone 05. It is very similar in its properties to the white clay over the ore at Lignite.

ROANOKE COUNTY.

Hollins.—Shale of probably Devonian age can be seen outcropping along the road about 2 miles northwest of Hollins (Field No. 58). It is dark-colored, of smooth feel, and weathers to a clayey mass. In its fresh condition the shale (Lab. No. 2233) does not give a mass of sufficient plasticity when ground and mixed with water to permit of its being molded.

The Cambro-Ordovician clays found nearer the station, and mentioned on page 48, are somewhat better.

SMYTH COUNTY.

Marion.—The Devonian rocks are not found near the railway, but a strong belt of them lies to the northwest, and strikes northeast-southwest. Large quantities of the Devonian (Chattanooga) shale are exposed along the wagon road $3\frac{3}{4}$ miles east of north from Marion (Field No. 82). The

rock which dips southeast can be traced by its exposures for at least 1,000 feet, and wherever seen is of argillaceous or clayey nature.

The shale (Lab. No. 2199) grinds up with 14 per cent of water to a mass of gritty feel and somewhat low plasticity, but still sufficient to permit of its being molded. The air shrinkage is very low, being 1.5 per cent. At Cone 010 the shale showed a fire shrinkage of .4 per cent, and an absorption of 15.1 per cent, while at Cone 05 the brick was steel hard, with a fire shrinkage of 1.7 per cent, and absorption of 8.45 per cent. Even at Cone 010 the bricklets had a very fair ring.

The material could be used for common brick, but the outcrop sampled is rather far from the railroad for economical working. If found in a better location it would be worth considering.

TAZEWELL COUNTY.

Richlands.—The Richlands Brick Company (Plate XII, A), one of the largest plants in western Virginia, is located at Richlands, the works being just southwest of the town (Field No. 85).

The raw material used is the Kimberling (Devonian) shale (Fig. 5), which is dug by steam shovel (Plate XII, B). At the works it is ground in a dry pan, tempered in a pugmill, and molded in a Freese side-cut machine. The drying is done in a tunnel dryer heated by waste heat, and burned partly in circular down-draft kilns and partly in scove kilns with permanent side walls. The product consists of building bricks and blocks; also 12 x 12 inch blocks for coke-oven bottoms.

The shale is obtained from a hill east of the works and dips slightly to the south. It is smooth and contains occasional sandstone layers and concretions, which are more abundant in the upper half of the bank. The shale also occurs in the low hills immediately south of the plant, and these in turn are bordered on the south by limestone.

The shale on the whole is smooth, but unless well ground the limonite grains and concretionary lumps are apt to produce pimples in burning, so that if the material were tried for sewer pipe attention would have to be given to the grinding and screening, in order to eliminate as much coarse material as possible.

This shale (Lab. No. 2333) is one of the best tested from western Virginia. When ground to pass 20 mesh, and mixed with 25 per cent water it works up to a mass of good plasticity. The tensile strength was 80 pounds per square inch, and the air shrinkage 4.8 per cent.

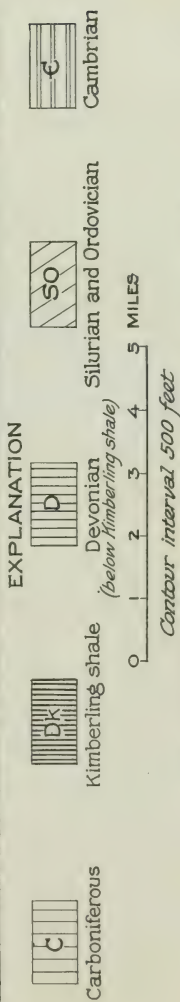
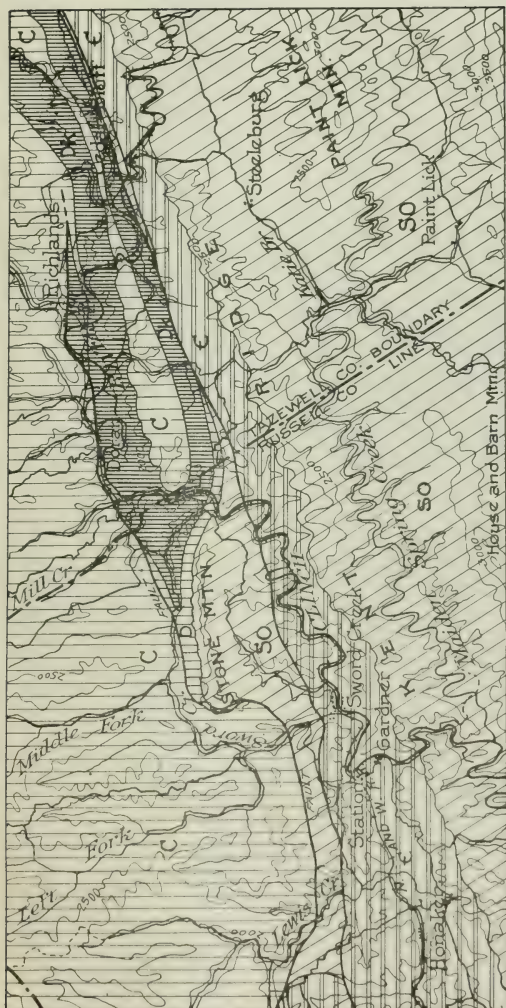


Fig. 5.—Geologic map of Richlands area, Tazewell County, Virginia.
(Tazewell Folio 44, U. S. Geol. Survey.)

The wet-molded bricklets behaved as follows in firing:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0	15.7
05	1.6	10.7
1	5.0	0.4
3	5.0	0.0
5	4.3	2.0

The clay burns to a good red color, gives a fair body at Cone 010, and is steel hard at Cone 04. It is vitrified at Cone 3, but was slightly overfired at Cone 5. A sample put through the stiff-mud machine worked well through the brick, hollow brick, and 3-inch tile die.

A third sample was molded dry press and gave a good brick with 11.40 per cent absorption at Cone 05.

WASHINGTON-SCOTT COUNTIES AREA.

The Virginia and Southwestern Railway follows the Chattanooga shale formation from Mendota, Washington County, to Hilton, Scott County. In this region the Chattanooga shale is mostly fine-grained and carbonaceous, although in the upper part of the formation the shale becomes more sandy and of a brown or ash color.

The chief line of outcrop is along the southern slope of Clinch Mountain where it forms what is known as Poor Valley, a term used on account of the poor quality of the soil, which is nearly white in color and ill-adapted to agriculture.

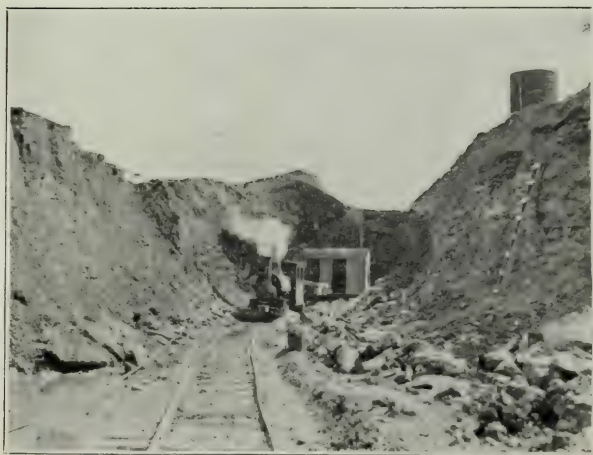
The weathered shale can be seen in cuts about one mile or so before reaching Hilton. There are also cuts of weathered shale along the railroad northeast of Maces Spring, Washington County.

Just east of Mendota there are cuts of sandstone and sandy shale, while beyond Mendota the cuts show residual clay derived presumably from shale, and about $1\frac{1}{2}$ miles beyond the station the cuts show the typical black Chattanooga shale.

Beyond Hilton about 2 miles there are cuts of a brownish shale, which extend nearly to Moccasin Gap (Fig. 6). One of these is situated about half a mile east of Moccasin Gap (Field No. 100), where the shale strikes a little north of east and shows a steep southeast dip. This is a brownish shale, cut by numerous joints, which together with the bedding planes show films of limonite. It belongs probably to the Chattanooga black shale formation, and may represent a weathered phase of it, but the many outcrops indicate that it is well worth testing out as to quantity.



(A) Plant of Richlands Brick Company, Richlands, Tazewell County.



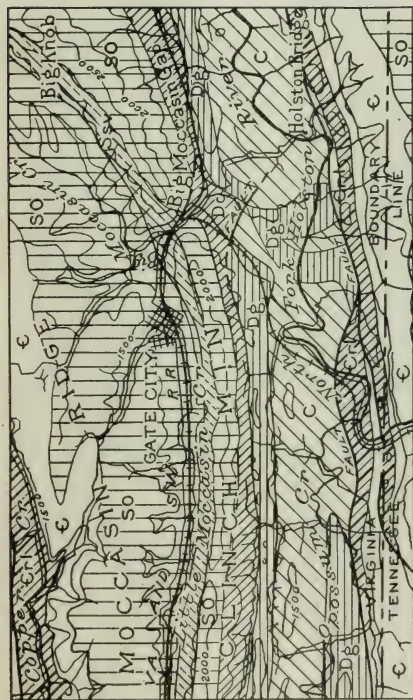
(B) Shale pit of same company.



(A) Shale bank, Rose Hill, Lee County.



(B) Mississippian shale, along road at Weldon, north of Pulaski, Pulaski County.



EXPLANATION

- | | | | | | | | | | | | |
|--|---------------|--|----------------|--|-------------------------|--|---|--|-------------------------------------|--|-------------------|
| | Carboniferous | | Grainger shale | | Chattanooga black shale | | Silurian and Sevier shale (except Sevier shale) | | Cambrian (except Russell formation) | | Russell formation |
|--|---------------|--|----------------|--|-------------------------|--|---|--|-------------------------------------|--|-------------------|

0 1 2 3 4 5 MILES

Contour interval 500 feet

Fig. 6.—Geologic map of Moreasin Gap area, Scott County, Virginia. (Estillville Folio 12, U. S. Geol. Survey.)

The material (Lab. No. 2337) works up with 22 per cent of water to a nice plastic mass. The air shrinkage is 3.8 per cent, and average tensile strength, 40 pounds per square inch. The shale was molded by hand and fired with the following results:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0	Too soft
05	1	13.4
1	2.6	9.1
3	3.6	4.5
5	4.3	3.1

The clay was steel hard at Cone 05 and burned red. A sample put through the stiff-mud machine flowed nicely through the brick die, but the material should be properly ground and screened if worked up in this manner. The results obtained in dry pressing were not very satisfactory unless the brick was fired above Cone 05.

On the whole this is a good shale, which burns fairly dense at a low temperature, and remains so for some cones without showing signs of over-firing. It would no doubt make hollow blocks, and is worth trying out for sewer pipe and paving brick. The deposit is located close to the railroad. It should be carefully prospected to determine whether it shows any marked change with depth.

Not far from here, and close to Moccasin Gap Station, the black shale crops at the surface, but it is much crumpled on account of being near a fault.

To the south of the brown shale mentioned above there are outcrops of black shale, brown shale, and sandstone. These last mentioned are all supposed to be in the Grainger formation, the lower part of which is Devonian.

WISE COUNTY

Oreton.—In the vicinity of Oreton (Fig. 7) the Virginia and South-western Railway passes through a number of shale cuts lying chiefly east of this locality. One large cut is a fourth of a mile (Field No. 94) east of Oreton, and shows a monocline of soft grayish shale containing scattered stains of limonite. Near the bottom of the cut there is a little black shale, but it seems extremely doubtful from the evidence at hand whether the gray shale is a weathered product of the black. About halfway up the cut is a bed of very clear gray clay, which resembles fire clay in appearance. There is a strong outcropping of hard black shale just west of Irondale Station.



Fig. 7.—Geologic map of region south of Big Stone Gap, Wise County, Virginia. (Estillville Folio 12, U. S. Geol. Survey.)

The shale (Lab. No. 2350) from the cut a fourth of a mile east of Oretou is very smooth and gives a mixture of good plasticity with 20 per cent of water. Its air shrinkage is 4 per cent, and its average tensile strength, 44 pounds per square inch.

The shale fires red, becoming deep red at Cone 1, at which cone it is practically vitrified. It is steel hard at Cone 05.

The following figures shows its behavior at the different cones:

Cone	Fire shrinkage Per cent	Absorption Per cent
010	0	16
05	2.6	8.5
1	4.3	1.0
3	3.4	.5

The shale does not burn hard enough at 010, but gives a good product at 05. It could probably be used for either brick or hollow blocks.

The bed referred to as occurring halfway up the cut and appearing less iron-stained than the rest is after all somewhat similar to the run of the bank, but shows a higher fire shrinkage. Its properties (Lab. No. 2336) may be summarized as follows: Water required, 26 per cent; plasticity, good; air shrinkage, 5 per cent; Cone 010: fire shrinkage, 0 per cent, absorption, 20.6 per cent; Cone 05: fire shrinkage, 5.3 per cent, absorption, 9.8 per cent; Cone 1: fire shrinkage, 10.6 per cent, absorption, .5 per cent.

The sample fires red, but not as deep as the run of the bank. Its uses are similar. This same type of shale is found in several other cuts farther east from Oretou.

LEE COUNTY.

Rose Hill.—A narrow belt of Devonian rocks extends across the northwestern part of Lee County and is traversed by the Louisville and Nashville Railway between Ocoonita and Rose Hill. At the latter locality (Field No. 102) the shale is exposed in the railway cut a few hundred feet northeast of the station, and is excavated for use at the local brick works. In the main pit (Plate XIII, A) the shale strikes N. 50° E. and dips 60° N. W., but there are also local irregularities of dip due to folding.

The shale is a soft argillaceous material, of brownish color, with organic matter along the bedding planes. It seems to be peculiarly free from concretions or sandstone layers.

The material (Lab. No. 2368) works up with 25 per cent water to a mass of good plasticity, whose air shrinkage is 4 per cent, and average

tensile strength, 22 pounds per square inch. It burns red, and is steel hard at Cone 05 or even lower. No trouble is experienced in running it through the die of a stiff-mud machine.

Burning tests of the wet-molded bricklets gave the following results:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	1	18.4
05	3.6	11.2
03	.....	.....
1	5	9.7
3	Viscosity beginning	

The clay, as the preceding tests show, fuses at a rather low cone, and has a somewhat short vitrifying range, but this does not interfere with its being burned to a good hard brick. It could also be used probably for fire proofing and drain tile. At Cone 05 it will yield a hard dry-pressed brick with 14.7 per cent absorption.

At the time of our visit the shale was being used for the manufacture of a side-cut, stiff-mud brick. The drying was done in tunnel dryers and burning in circular down-draft kilns. The company had also installed a continuous kiln.

MISSISSIPPIAN SHALES.

The Mississippian formation contains some of the best shales that were tested from western Virginia.

As the areas are so detached their location can best be understood by reference to the geologic map of Virginia, and suffice it to say here that the formation extends somewhat discontinuously along the western side of the Great Valley, the longest individual area being that which passes a few miles west of Blacksburg, Pulaski, and Marion. The Mississippian rocks in Virginia consist of shales, sandstones, conglomerates, and limestones. The shales in some cases are excellently adapted to the manufacture of clay products, while the limestones may yield residual clays. The sandstones and conglomerates are, of course, of no value to the manufacture of clay products. Most of the promising deposits lie in the southwestern part of the State. We take up first those lying close to the Valley region and next those lying near the western border of Virginia.

AUGUSTA COUNTY.

Stokesville.—The branch railroad from Harrisonburg to Stokesville traverses a short stretch of Mississippian rocks near its western terminus, and affords some excellent exposures.

There are large outcrops of shale and sandstone at Stokesville station. Along the railroad track the shale is fairly hard, often red, sometimes green, and contains sandy layers from 1 to 12 inches thick. The shale in its fresh condition does not develop sufficient plasticity to mold.

South of the station about an eighth of a mile the shale appears altered, is green or gray in color, breaks with a smooth fracture, and contains very little sandstone. It, too, however, does not work up to a sufficiently plastic mass to be used alone. The strike here is east-west and the dip to the north. One-quarter of a mile northwest of the station there is a reddish shale in abundance, but it also is lacking in plasticity. It is claimed that brick were once made about an eighth of a mile south of this point from a clay that is probably residual from the shale.

If any of the Stokesville shales were used it would be necessary to mix some clay with them.

MONTGOMERY COUNTY.

Merrimac.—We have here an oval-shaped area (Field No. 61) of Mississippian rocks surrounded on all sides by Cambro-Ordovician limestones and separated from them by faulting. Two railroads, one a branch of the Norfolk and Western Railway from Christiansburg to Blacksburg, the other the Virginian Railway, which divide the area into four unequal parts. The area is best known on account of the semibituminous coal which is mined. Excellent sections are seen in the cuts of both railroads. The rocks strike approximately east-west and dip to the south.

In the lower railway cut of the Virginian the rocks are practically all sandstone and very gritty hard shale. Some of the red shale at the west end of the cut is smoother than the rest, but it is too gritty to work and not much of it is exposed. This cut is all in the Price sandstone formation. The upper cut, on the Blacksburg branch of the Norfolk and Western Railway, likewise shows sandstone and sandy shale.

The best shale exposure found was along a road in the woods, south of the coal breaker, and perhaps an eighth of a mile from the main Christiansburg-Blacksburg road. Here there is a considerable outcrop of slightly weathered Pulaski shale. The rock is a dark gray-brown shale (Lab. No. 2305) which works up with 20 per cent of water and develops fair plasticity. The addition of a little clay would greatly improve the shale. The tensile strength is 27 pounds per square inch, and the air shrinkage, 3.6 per cent. It burns steel hard at Cone 05 and makes a good red brick.

The tests on the wet-molded bricklets were as follows:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0	17.3
05	2	11.6
1	1	4.8
3	Nearly viscous	

The material is not adapted to making paving brick, but is all right for common brick. A sample of it was dry pressed, and at Cone 05 gave a red brick with 11.2 per cent absorption and a good ring.

Considerable shale is exposed around the Merrimac coal mine, but the exposures are small, and, in most cases, seem to represent weathered material. Some partial tests of several samples collected from the hill opposite the coal breaker will give some idea of the variety. It should be emphasized that, in every case, the sample collected represents somewhat weathered shale, for we were not able to get down to the fresh rock.

1. Sample from an east-west road about 100 yards north of Merrimac mine (Lab. No. 2178). Also about 200 yards from mine. Strike N. 85° E. and dip 60° N. This is a greenish-gray shale, which is very smooth and plastic. Water required, 30 per cent. Air shrinkage, 3.4 per cent. Cone 010: fire shrinkage, 0 per cent, absorption 46.5 per cent; Cone 05: fire shrinkage, 1.7 per cent, absorption, 27.5 per cent. Does not fire dense enough to make a good brick, but gives a red product.

2. Dark shale underlying coal, from cut just southeast of mine and across trestle (Lab. No. 2148). Strikes N. 85° E., dip 40° N. Quantity, uncertain. Plasticity, fair, but clay gritty. Water required, 13 per cent. Air shrinkage, 4.9 per cent. Cone 010: fire shrinkage, 0 per cent, absorption, 12.5 per cent; Cone 05; fire shrinkage, .3 per cent, absorption, 11.8 per cent. This would make brick. It burns red.

3. Shale along narrow-gauge road opposite Merrimac mines (Lab. No. 2160). Strike N. 60° E., dip 40° S. E. Fifty feet exposed along track. Plasticity, high, but required only 19 per cent water for mixing. Air shrinkage, 4 per cent. Too soft at Cone 010, but at Cone 05 has fire shrinkage of 1 per cent, and absorption of 14.3 per cent.

4. Fine-grained black shale outcropping just back of Merrimac mine (Lab. No. 2135). Strike N. 60° E., dip 40° S. E. Plasticity, fair. Air shrinkage, 1 per cent. Too soft at Cone 010. At Cone 05: fire shrinkage, 1 per cent, absorption, 12.6 per cent.

PULASKI COUNTY.

Weldon.—North and west of Pulaski is a considerable area of Mississippian rocks, which forms a tongue extending southward from the main belt lying a few miles to the northwest.

These rocks outcrop along the line of the Norfolk and Western Railway, southwest of Pulaski for two miles or more, but they are unpromising, being sandstones or sandy shales. Indeed the only bed of smooth shale seen was one 4 feet thick in a cut 2 miles southwest of Pulaski (Field No. 66). Even this (Lab. No. 2113) is very sandy, although at Cone 05 it burns red, with 8.1 per cent absorption, and has a good ring. Its location is such, however, as not to recommend it.

Going north from Pulaski, however, there is abundant evidence of shale in the road cuttings, and along the macadam road about 4 miles north of Pulaski, and about 100 yards east of Walden station (Field No. 67), on the old Altoona branch road, is a long cut showing a section of shale about 300 feet long and 15 feet high (Plate XIII, B).

Between the wagon road and the old railroad grade there is a residual clay deposit evidently derived from the shale, and this was used a number of years ago for brick-making, the Major Bentley house near here being built of the bricks.

A sample of the shale was taken by mixing material from vertical cuttings from top to bottom of different parts of the face, after first cleaning off the visibly weathered material. This sample (Lab. No. 2323) was then tested, as was also a sample of the residual clay (Lab. No. 2324). The two sets of tests are given below:

	2323	2324
Water required	17%	26%
Plasticity	Fair	High
Air shrinkage	3	5.2
Tensile strength, lbs. per square inch.....	36	65
Wet-molded bricklets		
Cone 010		
Fire shrinkage	0	0
Absorption	13.6	18
Cone 05		
Fire shrinkage	2.6	3.6
Absorption	9.6	10.9
Cone 03		
Fire shrinkage	4	....
Absorption	6.33	....
Cone 1		
Fire shrinkage	4.5	7.3
Absorption	4.6	2.9
Cone 3	Nearly viscous	Nearly viscous
Color after firing	Red	Red
Steel hard	05	05

The shale was tried in a stiff-mud machine with both the brick and the hollow-ware die, and gave no trouble whatever. It would probably be best to grind it in a wet pan, as it shows a little tendency to remain granular.

The clay gave an excellent dry-press brick at Cone 05. Its total shrinkage at Cone 1 is not excessive. It would probably be best to use the clay in connection with the shale. This is one of the most easily accessible shale areas in the State, but the ground should be carefully prospected before locating a shale pit.

SMYTH COUNTY.

Marion.—Three miles north of Marion (Field No. 83), the gray to brown Mississippian shales are exposed in a road cut about 100 yards long and 10 feet deep. The material at the time the sample was taken had not been exposed more than four months. The shale is quite uniform, and has no sandy layers. It strikes northeast-southwest, and the dip is nearly vertical. Although the deposit is at present a little far from the railroad, it is so located that it could be easily worked.

The following tests were made of this shale (Lab. No. 2191):

Water of plasticity	25%
Plasticity	Good
Tensile strength, lbs. per sq. inch	35
Air shrinkage	2.8%

Fire tests:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0.0	16.1
05	2.0	13.9
03	3.4	4.6
1	6.0	3.1
3	8.0	1.7
5	7.6	1.6
7	6.0	1.4
9	5.0	1.2
Color after firing		Red
Steel hard		Cone 05

The clay fires to a good body, of low total shrinkage, and would work well for brick, hollow blocks, and drain tile. It is also of promise for paving brick.

North Holston.—The Mississippian rocks are accessible in the valley of the North Fork of Holston River, northeast and southwest of Saltville, and their relations have been described by Stose.^a The members of the Mississippian occurring here are the Newman limestone, Maccrady formation, and Price sandstone.

^a U. S. Geol. Survey, Bulletin 530, p. 232, 1913; Va. Geol. Survey, Bull. No. VIII, 1913, p. 51.

In the Holston Valley these rocks have been bent into a syncline or basin, whose northwest limb forms Brushy Mountain, north of Holston, while the southeastern limb is cut off by an overthrust fault. The Price sandstone, which is the lowest member of the three formations, outcrops on the slopes of Brushy Mountain, but on the other side is concealed by the fault. It consists of sandstone and shaly sandstone, and is probably of no value. The Maccrady formation may carry sandstone, limestone, and shale, and underlies the valley at North Holston, but is usually covered by stream deposits. The material is abundantly exposed in the gypsum mines, where some samples were obtained. Its lower members consist of a basal black shale and reddish sandy beds, and the latter are exposed on the lower slopes of Brush Mountain along the track leading from Saltville to the gypsum mill at North Holston. These shales are sometimes very sandy, but at other times they are quite argillaceous, when they grind up to a material of good plasticity.

A belt of the Maccrady continues southwest from Saltville following the valley of the North Fork of Holston River, but here it lies more remote from the railroad.

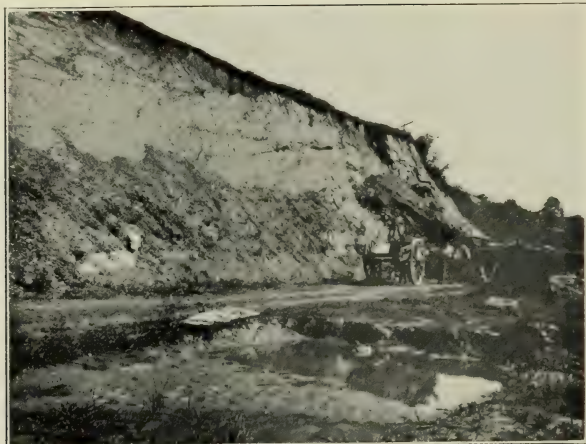
Three samples were collected for testing. The first of these (Lab. No. 2346) was collected from the lower beds of the Maccrady formation, as exposed along the tracks near the gypsum mill at North Holston (Field No. 84). Two others were obtained from the gypsum mines at North Holston and represent the red (2347) and the gray (2348) shales associated with the gypsum.

The first-named material (Lab. No. 2346) is yellowish-brown and smooth. It worked up with 43 per cent of water to a mass of high plasticity, with 9.5 per cent air shrinkage, and 60 pounds per square inch tensile strength.

Bricklets of the wet-molded clay gave the following results:

Cone	Fire shrinkage	Absorption
	<i>Per cent</i>	<i>Per cent</i>
010	0	20.2
05	6.6	11.6
1	12	1.3
3	10	1.5

The bricklets fired red, and were nearly steel hard at Cone 010. The material worked well through the stiff-mud machine, but the main objection to it is its high air shrinkage. The fire shrinkage at Cone 1 is also high, but there is no trouble about the color. It would be desirable to mix this clay with one of lower shrinkage, when it could probably be used in a



(A) Slightly weathered Bluefield shale, Tip Top, Tazewell County.



(B) General view of Tip Top brick works, Tip Top, Tazewell County.

hollow-block or drain-tile mixture. The material can also be dry pressed, but at Cone 05 gave a somewhat porous brick, with 21.2 per cent absorption.

The red shale from the gypsum mine is smooth and contains abundant grains, as well as small lumps of gypsum. It should, therefore, be properly screened and ground before using. If so prepared, the material develops very good plasticity with only 17 per cent of water. The average tensile strength is 45 pounds per square inch, and the air shrinkage, 4 per cent. The clay works well in a stiff-mud die, and the gypsum lumps cause no trouble if properly ground beforehand.

The molded bricklets gave the following results on firing:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0	15.3
05	4	7.4
03	6	1.0
2	1	1.3

The shale fires red, and is steel hard at Cone 010. It is beyond vitrification at Cone 2. After firing the gypsum shows as small white specks, but these do no harm. The material could be used for brick and probably hollow brick. It would be desirable to mix it with No. 2346.

A sample was also dry pressed and gave a steel hard brick with 13.3 per cent absorption at Cone 05, but was too soft at Cone 010.

The dark gray shale associated with the gypsum was also tried with interesting results. This shale (Lab. No. 2348), although very plastic, needed but 18 per cent of water for working. The air shrinkage was 3.9 per cent, and the average tensile strength, 34 pounds per square inch. It would probably work in a stiff-mud machine. The clay burns red, and is nearly steel hard at Cone 010. At this same cone the fire shrinkage is 0 per cent, and absorption, 15.4 per cent, while at Cone 05 its fire shrinkage and absorption were, respectively, 1 and 11.1 per cent. The shale is beyond vitrification at Cone 1. It can also be dry pressed.

The gray shale is very similar to the red gypsum shale, but differs from it chiefly in not burning as dense at Cone 05. The two should be mixed together and could be used for the same classes of ware.

WASHINGTON COUNTY.

Benhams.—The Virginia and Southwestern Railway crosses the Mississippian shale belt for several miles north and northwest from Benhams, but the material appears to be of little value. Just south of Benhams the bedrock is limestone.

TAZEWELL COUNTY.

Tip Top.—The Tip Top Brick Company (Field No. 86) is making a red building brick from the weathered Bluefield shale which outcrops on the north side of the railroad (Fig. 8). The shale strikes N. 60° E. and dips 60° S. E. On the south side of the track the overlying Greenbrier limestone outcrops, and is covered in places by residual clay.

The shale is soft, the upper six feet being so completely weathered that the structure is obliterated, but the portion below this, although soft enough to work easily, still preserves its shaly structure.

The three following series of tests show the properties of the completely weathered shale (Lab. No. 2339), the partly weathered shale (Lab. No. 2340), and a mixture (Lab. No. 2378) of equal parts of the two:

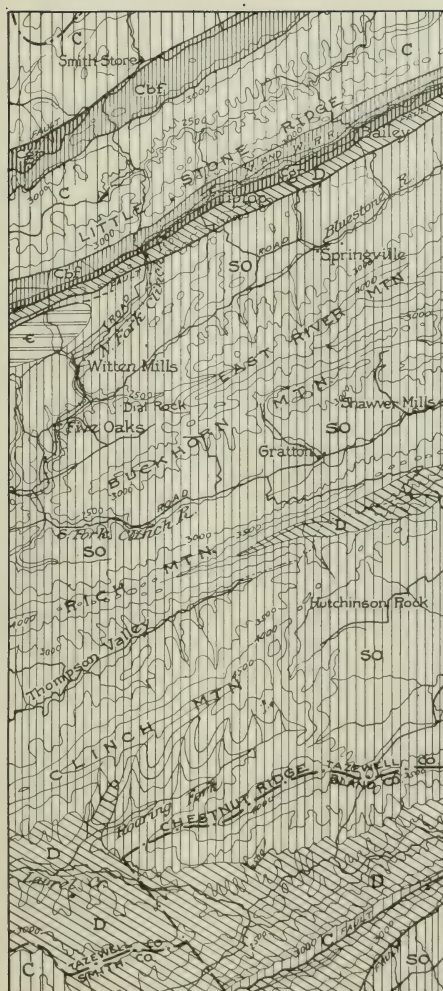
	2339	2340	2378
Water of plasticity	37	31	25
Plasticity	High	Good	Good
Air shrinkage	5%	4%	4%
Tensile strength, lbs. per sq. inch.....	60	40	70
Cone 010			
Fire shrinkage	2	0	0
Absorption	28.5	25.7	27.9
Cone 05			
Fire shrinkage	5	3.3	2.6
Absorption	17.5	18.4	20.9
Cone 1			
Fire shrinkage	14.0	9.0	8.0
Absorption	3.0	3.7	9.6
Cone 3			
Fire shrinkage	10.6	3.6	11.6
Absorption	.9	1.1	.2

Lab. No. 2339. The clay fires to a red color. At Cone 05 it has a good hard body. Shrinkage too high at Cone 1 to use clay alone at this temperature. Nearly steel hard at 010, and fully so at 05. Works well dry press and at Cone 05 had 3.0 per cent fire shrinkage, and 16.9 per cent absorption. It is overfired at Cone 3.

Lab. No. 2340. Barely hard enough at Cone 010, but has a good hard body at 05. Shrinkage somewhat high at Cone 1. Fires to a red color.

Lab. No. 2378. Excellent hard body at Cone 05, but absorption somewhat high. Fires to a red color. Mixing the shale and clay tends to reduce the fire shrinkage. A good brick material, which could probably be used also for hollow brick.

Plate XIV, (A), shows the bank of weathered shale, and (B) a general view of the brick-making plant.



0 1 2 3 4 5 MILES

Contour interval 500 feet.

EXPLANATION



Bluefield shale



Greenbrier limestone



Carboniferous
(except Bluefield
shale and Greenbrier
limestone)



Devonian



Silurian and Ordovician



Cambrian

Fig. 8.—Geologic map of Tip Top area, Tazewell County. (Pocahontas Folio 26, U. S. Geol. Survey.)

LEE COUNTY.

Pennington.—Shales of probably Mississippian age outcrop at several points in the vicinity of Pennington, but the exposures are not in all cases very extensive.

One of these occurrences (Lab. No. 2358) is 100 yards south of the Junction of the Virginia and Southwestern and Louisville and Nashville railways, or about 2 miles west of north of Pennington (Field No. 103). The shale deposit is about 30 feet wide, but not in a very accessible position, and would not be of much use, unless it could be traced to a better-located point. The material makes a good brick shale if ground sufficiently fine, for it has enough plasticity to mold. The air shrinkage is zero. At Cone 010 the fire shrinkage was 1.6 per cent, and absorption, 11.1 per cent, while at Cone 05 these values were 2 and 8.7 per cent, respectively. The material, therefore, fires to a body of moderate absorption, and good red color. No further tests were made as the exposure was limited. Similar shale appears at different points for a mile south of the railroad junction, but may contain sandstone beds.

Three-quarters of a mile south of Pennington (Field No. 108) is a four-foot deposit of gray shale (Lab. No. 2359) of unknown extent, but which works up with 26 per cent of water to a mass of good plasticity, and 5 per cent air shrinkage. It fires to a red color and gives a good brick at Cone 05. The mixture in firing had 0 per cent fire shrinkage, and 16.4 per cent absorption at Cone 010, while at Cone 05 the fire shrinkage was 3.3 per cent, with 8.2 per cent absorption. At Cone 3 the fire shrinkage is 8 per cent, and absorption 2 per cent. So far as its physical qualities are concerned this is a good brick material.

One mile north of Pennington (Field No. 101) is a clay deposit, representing what is probably residual wash from Mississippian shale. It (Lab. No. 2360) is gritty, but has excellent plasticity, and 7 per cent air shrinkage. The material burns to a buff color and is more refractory than most of the clays that have been found, as the following tests show:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0	16.4
05	.6	14.1
5	3.3	9.0

This material could probably be used for face brick. It might do for boiler settings.

CARBONIFEROUS FORMATIONS.

The Carboniferous rocks occupy an extensive area in southwestern Virginia covering all of Buchanan and Dickenson counties, a large portion of Wise County, and the northwestern edge of Tazewell, Russell, Scott, and Lee counties. They consist almost entirely of sandstones and conglomerates, with important beds of coal, and consequently do not offer a very promising field to the clay worker. Moreover, a large portion of the area is not traversed by railroads.

The only railroad passing entirely across the area is that running from Frick on the Clinch Valley division of the Norfolk and Western, through Dante to Elkhorn City, Kentucky. Along this line there are a number of sections, but none of them exposes any shales of value.

Here and there thin beds of shale are found, some of them underlying coal seams. Special inquiry was, therefore, made at the different coal mines with a view to obtaining all possible information regarding these. There is a popular and widespread theory that all clay or shale under coal is fire clay. This is not the case. All under clays are not fire clays, nor are all fire clays found under coal beds as many people also believe.

It is, furthermore, not possible to tell from the appearance of a clay or shale under coal whether it is refractory or not. Some of the coals of southwestern Virginia are underlain by sandstone and not by clay.

The localities examined are described below.

RUSSELL COUNTY.

Dante.—Underlying the coal in Mine No. 2 of the Clinchfield Coal Corporation, 1 mile north of Dante (Field No. 93), there is below the coal at least 6 feet of gray sandy shale, but the total thickness is not known. The upper 6 inches is darker in color and more fossiliferous. While the material underlies the coal throughout the mine, it grades into sandstone in places.

An average sample of the material (Lab. No. 2362) showed that it had good plasticity when worked up with 20 per cent water. Its average air shrinkage was 4.4 per cent.

Two samples were fired. One of these at Cone 010 showed zero per cent fire shrinkage, and 18 per cent absorption. The other fired at Cone 05 was steel hard, had 1.6 per cent fire shrinkage, and 13 per cent absorption. The clay has to be fired slowly to prevent black coring. It should make a good hard brick, but would have to be mined in conjunction with the coal. It is not a fire clay.

Just at the portal of the tunnel 2 to 3 feet of the shale are exposed; it is weathered and quite plastic (Lab. No. 2363). This probably accounts for its high fire shrinkage. The air shrinkage is also slightly higher, namely, 52 per cent.

Firing tests were as follows:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	.7	21.1
05	3.7	12.6
1	8.3	2.3
3	Beyond vitrification	

The clay has a slow oxidation period, but fires to a red color, which becomes very deep at Cone 1. It had begun to swell at Cone 3, as it was beyond vitrification. It was steel hard at Cone 05. It should make a good brick material.

WISE COUNTY.

Norton.—About $1\frac{1}{2}$ miles northwest of Norton on the main road (Field No. 105) and just east of the fork where the road to Big Stone Gap turns off is a cut 100 feet long and 15 feet high, showing beds of altered sandy shale with a steep dip. The material (Lab. No. 2356) is one of the best exposures in this district. It is yellow to brown, usually sandy, and may vary from hard sandy material to soft shale. There are other outcrops in the vicinity that look better than this one, but they are all smaller. For this reason the largest one was sampled. In spite of its sandy feel, the shale when ground to pass a 20-mesh sieve, and mixed with 25 per cent of water, had good plasticity. The tensile strength of 25 pounds per square inch was low, but this affects its bonding power more than its ability to work in a stiff-mud machine. The air shrinkage is 4 per cent. It fires to a good red color, and is steel hard at Cone 05.

The details of firing tests are as below:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0	20.8
05	2.8	16.4
03	4.0	12.0
1	5.0	10.7
3	8.3	2.9
5	7	6

These tests show that the material had begun to overfire at Cone 5. The shale should make a good brick.

Glamorgan.—The Stonega Coal and Coke Company has mines in operation at Glamorgan (Field No. 95). Under the coal is an 18-inch bed of so-called fire clay (Lab. No. 2353), which is gray, smooth and plastic, and lies nearly flat. The material has excellent plasticity when worked up with 27 per cent of water, a tensile strength of 25 pounds per square inch, and an air shrinkage of 4.5 per cent.

At Cone 010 the fire shrinkage is .7 per cent, and the absorption, 21.2 per cent, while at Cone 05 the clay shows 2.4 per cent fire shrinkage, and 18.3 per cent absorption. At Cone 5 the material is beyond vitrification, so that it is not a fire clay. The color after burning is pink. Material of this type could be used for brick if there were enough of it.

Just north of Glamorgan (Field No. 96) on the Pound road is gray clay (Lab. No. 2352), which is very plastic and smooth, but which if it is derived from shale is very much weathered, for there is no trace of the original rock structure remaining. This clay which has an air shrinkage of 6 per cent, burns pale red, and shows an additional shrinkage of 1 and 2 per cent at Cones 010 and 05, respectively, with an absorption at both cones of close to 20 per cent. While it does not burn very dense, it is capable of making a good common brick, if the quantity proves to be sufficient.

Wise.—About three-fourths of a mile south of Wise (Field No. 97) in a road cut several hundred feet long is a somewhat characteristic section of materials associated with the coal. Here below a 1-foot coal seam is a gray clay, and over it is sandy shale, red sandy clay, gray and brown clay. It is probably weathered material, and so may be regarded as somewhat better than it would be farther in the deposit. However, the face of the bank as exposed and averaged (Lab. No. 2354) shows good plasticity with 5 per cent air shrinkage. It fires red, but while it gives a good brick at Cone 05 it is not steel hard.

The fire shrinkage and absorption at Cone 010 are, respectively, 0 and 22.2 per cent, while at Cone 05 they are 1 and 18.8 per cent. A perfectly salable brick could be made from this clay-shale mixture.

In the area around Norton the Carboniferous rocks are mostly sandstones, but there are occasional exposures of shaly sandstone or sandy shale 5 or 6 feet in thickness. Since they are interbedded with sandstones, they could only be extracted by underground workings. Some of these weather to a light plastic clay, while others break down to a sandy clay.

Of the former type we find an example half a mile north of Wise, on the Wise-Glamorgan road (Field No. 98). The material here (Lab. No.

2319) is a mixture of gray plastic and sandy brown and yellow clay, most of which still preserves the original rock structure. The beds lie nearly flat.

This is a rather good material. It develops good plasticity when worked up with 24 per cent of water, and had an air shrinkage of 4.6 per cent.

The firing tests were as follows:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	0	19.8
05	.4	17.3
03	4.0	2.5
1	5.6	2.5
3	6.0	.3
5	5.0	1.5

The clay fires red and has a very low absorption from Cone 03 to Cone 3, at which heat it showed no signs of failure. If there was a sufficient quantity of it, the material could probably be used for drain tile or hollow blocks.

It will be noticed from these tests that the shale reached its maximum shrinkage and density a little above Cone 3, and at Cone 5 it was a little beyond vitrification, as shown by the decreased shrinkage and increased absorption. This should be a good shale for such purposes as hollow brick and drain tile.

Kent Junction.—There is little else but sandstone exposed around Kent Junction, but about half a mile northwest of the Junction a section showing alternating bands of sandy shale and clay occurs. It was not sampled.

Appalachia.—Between $2\frac{1}{2}$ and 3 miles northeast of Appalachia (Field No. 99), on the road to Norton is a cut of altered shale, which has not fully weathered as the entire rock structure is still quite clearly retained. The outcrop here is about 50 x 8 feet, but there are several similar cuts between here and Kent Junction. The material (Lab. No. 2355) takes but 17 per cent of water to work it up, but has good plasticity. The air shrinkage is 3 per cent. It fires to a good red body. Firing at three different cones gave the following results:

Cone	Fire shrinkage <i>Per cent</i>	Absorption <i>Per cent</i>
010	.3	15.4
05	4.6	9.0
1	8	3.2

Even at Cone 1 the clay shows no signs of overburning and the total shrinkage is not high. It would no doubt work for brick and fire proofing.

Stonega.—The rock around Stonega, where exposed, is practically all sandstone, although at the coal mines there are from 6 to 8 feet of sandy shale, but the shale does not feel very plastic when wet.

LEE COUNTY.

Pennington.—Under the coal at St. Charles, especially in the Darby mine, there are 4 feet of a gray shale, which is referred to as fire clay. It is, however, very sandy and micaceous, and could not be used unless some more plastic material were mixed with it.

RECENT SEDIMENTARY CLAYS.

The surface (Recent) sedimentary clays are all of the flood-plain type. In many parts of the Valley region, and to a lesser extent in the Mountain region, the streams are bordered, in places at least, by terraces that may be from perhaps 2 to 15 feet above their present level. These flood-plain terraces, often covered by water during periods of flood, are underlain by river deposits, which may vary from fine clay to coarse sand, or sometimes both, the material being interlayered regularly, or sometimes in the form of interlocking lenses. On account of their irregularity it is therefore necessary to test them out quite carefully as to depth and extent. Some clue to the character of the material underlying the flood-plain can often be obtained from an examination of the river banks.

Where the material is clay it is usually apt to be more plastic and have a higher tensile strength than the residual clays: and this may be true even though the clay is very gritty.

Few of the flood-plain clays, however, are suitable for any clay product other than common brick, and they are so employed in many localities.

It is an interesting and noticeable fact that in any region where there is a brickyard, and where both residual and flood-plain clays occur, the latter are commonly used.

Aside from their adaptability, the flat surface of the flood-plain makes a good site for the location of a plant.

MODERN FLOOD-PLAIN DEPOSITS.

Fewer flood-plain clays are worked in the Valley region than in the Piedmont province east of the Blue Ridge. The following localities in the Valley province may be mentioned.

ROCKINGHAM COUNTY.

Bridgewater.—A small brickyard is in operation here, utilizing a flood-plain clay (Field No. 15).

AUGUSTA COUNTY.

Basic.—Just south of Basic (Field No. 37) and west of the Norfolk and Western Railway tracks is a flood-plain deposit which is underlain near the brick works by 4 to 5 feet of yellow, gray, and red clay, and this in turn by a gray sandy clay. Like most flood-plain deposits the clay is pockety. The top clay alone is used, it being claimed that the sandy clay is not good. Some partial tests of the two given below afford an interesting comparison. No. 2188 is the brick mixture of the yellow, gray, and red clay. No. 2190 is the bottom sandy clay.

	No. 2188	No. 2190
Water required	23	17
Plasticity	High	Good
Air shrinkage	5.3	3.4
Cone 010		
Fire shrinkage	1.0	0
Absorption	16.7	13.3
Cone 05		
Fire shrinkage	1.0	.3
Absorption	16.4	12.5
Cone 1		
Fire shrinkage	4.7	...
Absorption	11.7	...
Color burned	Red	Red
Steel hard	Cone 05+	Cone 05

The sandy clay does not work as well as the top clay, hence it is probably not desirable for use alone. It also has a somewhat lower plasticity and air shrinkage as might be expected, but it fires denser, and with a lower shrinkage than the top clay. There seems no reason why some of it should not be mixed with the overlying material.

The clay at this yard was not only being used for common brick, but also for drain tile, and seemed to yield a good product.

Lipscomb.—One-half mile southwest of Lipscomb (Field No. 16)^a is a low flood-plain deposit bordering South River, which contains one of the best flood-plain clays seen in the State. There is not more than 18 inches of top soil, while under this there is at least 6 feet of clay as exposed in the

^a The field number 16 also includes a residual clay locality, the two being so close together that the scale of the map prevents them being shown by separate field numbers.

stream banks. The sample was taken about 100 feet east of a private bridge across the creek, although the clay is exposed at a number of other points in the river banks.

The clay (Lab. No. 2195) gave the following tests:

Plasticity	High
Water of plasticity	35%
Average tensile strength, lbs. per sq. inch.....	311
Air shrinkage	9%

Firing tests:

Cone	Fire shrinkage	Absorption
	Per cent	Per cent
010	1.0	11.50
05	2.6	11.40
03	2.8	6.79
1	2.6	6.70
3	4.0	3.40
5	4.4	1.90
7	3.9	2.6
9	2.0	2.4

Color after firing red, turning to gray at Cone 3.

Steel hardCone 010

The clay fires to a very hard body of low absorption, and does not begin to overfire until Cone 7. It was not fused at Cone 9. It would make drain tile or other dense-burning wares calling for this type of clay. It was also tried with success in the stiff-mud machine, and flowed through the die without cracking.

The clay could be used for making both brick and drain tile, but the main objection is its high air shrinkage. This could be overcome by mixing a more sandy clay with it. As most flood-plain deposits are apt to contain lenses of sandy clay, some could perhaps be found in this one, or there is the possibility that mixing some of the near-by limestone residual clays would also help it.

A similar flood-plain clay is said to occur along South River south of Stuarts Draft.

ROCKBRIDGE COUNTY.

Goshen.—A small flood-plain deposit was formerly worked near the old blast furnace (Field No. 38), one mile south of Goshen, but no bricks have been manufactured here for some years.

ALLEGHANY COUNTY.

Covington.—There is a small flood-plain deposit on the southern edge of Covington (Field No. 43). The material is quite silty, and is dug to a

depth of about 6 feet. It is worked up in a pugmill and molded in an end-cut, stiff-mud machine. The bricks have a good ring, but the clay fires to a rather deep red. The yard is operated by the Covington Brick Company.

ROANOKE COUNTY.

Roanoke.—The Adams, Payne, and Gleaves Company is operating a yard east of Roanoke (Field No. 59). The deposit is of the flood-plain type and lies between Roanoke River and Tinker Creek. In this deposit they have made a long excavation 6 to 8 feet deep, which exposes a blue, sandy, but very plastic clay. At the upper end of the pit near the works, but away from the river is a very sticky clay, but this is not used. The clay is excavated with a steam shovel, and worked in a stiff-mud machine. It fires red, and the bricks have 11 per cent absorption. Only common brick are made.

Salem.—The Salem Brick Works located 2 miles west of Salem is using a flood-plain clay (Field No. 56)^a, which lies on the north side of Roanoke River. The flood-plain clay is mixed with a limestone residual clay obtained near-by for making common brick. It is referred to on page 48.

TERTIARY FLOOD-PLAIN CLAYS.

MONTGOMERY COUNTY.

Radford.—One mile more or less southwest of Radford (Field No. 62^b), at about the 2,100-foot elevation above sea-level, on the Nelson No. 1 property, there is a winding depression resembling a stream valley, which is underlain by clay that has been exposed in many test pits. The material is grayish in color, but there are two distinct types as one might expect to find in a flood-plain deposit. One is a tough, fine-grained clay, the other is a more sandy one. Both clays are found only in the depression referred to, and do not underlie the slopes surrounding it. The sandy clay is far more abundant than the smooth one. The two clays are so different that it is interesting to give the tests of them side by side for comparison.

	No. 2325	No. 2372
Water required	39	26
Plasticity	Good	High
Air shrinkage	4.7	8.0
Tensile strength	80	221.0

^a This field number also covers a deposit of residual clay from limestone which is located close to the flood-plain clay.

^b This field number also covers a deposit of red-burning clay located close to the flood-plain deposit.

Cone 010		
Fire shrinkage	0	.7
Absorption	10.0	16.5
Cone 05		
Fire shrinkage	0	1
Absorption	10.0	13.5
Cone 1		
Fire shrinkage	0	3.3
Absorption	11.2	11.5
Cone 3		
Fire shrinkage .....	....	3.0
Absorption .....	....	8.2
Cone 5		
Fire shrinkage	0	3.0
Absorption	11.0	7.4
Cone 9		
Fire shrinkage	0	....
Absorption	10.6	....
Color after firing	Buff	Buff
Steel hard	Cone 5	Cone 010

No. 2325 is the sandy clay.

No. 2372 is the smooth clay.

Both clays have a low fire shrinkage, and neither shows a high absorption at either cone. Both burn to a fine buff brick, and should make a face brick. It would be best to mix some of No. 2325 with No. 2372.

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CLAY LOCALITIES

INDICATED ON THE MAP BY RED DOTS AND NUMBERS

MAP NO.	LOCAL. NO.	NEAREST TOWN	PAGE	MAP NO.	LOCAL. NO.	NEAREST TOWN	PAGE
1		Mountain Falls	76	57	(2229)	Bonsack	60
2	2286	Winchester	69	58	(2227)	Hollins	87
3	(2217)	Berryville	39	59	2233	Roanoke	112
4	2219	Riverton	40	60	2300	Blacksburg	31
5	2220	Strasburg	40		(2301)		
6	2292	Woodstock	59		(2178)		
7	2294	Woodstock	70	61	(2146)	Merrimac	96
8	2369	Strasburg	70		(2160)		
9	(2290)	Strasburg	70		(2135)		
10	(2291)	Filton	41	62	(2116)	Railford	48, 76, 112
11	(2224)	Harrisonburg	41		(2326)		
12	(2225)	Harrisonburg	42	63	(2325)	Christiansburg	74
13	2225	Dayton	42	64	(2121)	Hiwassee	36
14	(2280)	Harrisonburg	71	65	(2124)	Hiwassee	36
15	(2281)	Bridgewater	110	66	(2113)	Pulaski	98
	(2138)			67	(2123)	Weldon	98
16	(2139)	Lipscomb	12, 110		(2124)		
	(2194)			68	(2141)	Porter Falls	38
17	2173	Stuarts Draft	19		(2143)		
18	2197	Cold Spring	19	69	(2097)	Ivanhoe	50
	(2163)			70	2111	Ivanhoe	50
19	(2176)	Lifton	20	71	(2110)	Austinville	50
	(2124)				(2127)		
20		Pekin	23	72	2147	Wytheville	51
21	2265	Baie	73	73	(2083)	Wytheville	61
22	2272	Staunton	43	74	(2137)	Marion	52, 64
23	2273	Staunton	43	75	2133	Marion	52
24	2193	Baie	26	76	2153	Marion	52
25	(2267)	Staunton	72	77	2321	Marion	53
26	(2268)	Staunton	72	78		Marion	63
27	(2276)	Portwick	80	79	2146	Marion	63
	(2277)			80			
28	2247	Millboro	79	81	(2331)	McMullin	65
	(2165)				(2373)		
29	(2173)	Venassias	28	82	2199	Marion	87
	(2174)			83	(2191)	Marion	99
	(2181)			84	(2346)	North Holston	99
30	(2182)	Buena Vista	24		(2348)		
	(2183)			85	2333	Richlands	88
31	2154	Buena Vista	25		(2339)		
32	2157	Lexington	44	86	(2340)	Tip Top	102
33	2155	Buena Vista	44		(2378)		
34	2156	Buena Vista	45	87	2328	Chilhowie	53, 61
35	2158	Buena Vista	45	88	2367	Castlewood	32
36	2271	Goshen	78	89	2361	Kuer	33
37	(2198)	Basic	110	90		Carterton	33
38	(2190)			91		Castlewood	33
39	2245	Longdale	91	92	2365	Honaker	33
40	(2260)	Longdale furnace	82	93	(2362)	Dante	115
	(2259)				(2363)		
41	2240	Low Moor	83	94	(2350)	Oreton	92
42	2242	Chen Wilton	84	95	2353	Glamorgan	107
43		Covington	111	96	2352	Glamorgan	107
44	(2304)	Nave	45	97	2354	Wise	167
	(2306)			98	2349	Wise	167
45	2236	Daleville	46	99	2355	Appalachia	108
46		Medians	48	100	2357	Hilton	91
47		Blue Ridge Springs	47	101	(2318)	Pennington	73, 114
48	2237	Lithia	30		(2368)		
49	2238	Flucastle	56	102	2365	Rose Hill	99
50		Buchanan	103	103	2358	Pennington	114
51	2309	Cloverdale	56	104		North Mountain	79
	2254			105	2356	Norton	106
	(2253)			106	(2263)	Covington	83
52	(2307)	Webster	57	107	(2264)		
	(2308)				(2192)	Ivanhoe	49
	(2313)			108	(2196)	Pennington	104
53	(2344)	Lignite	84	109	2359	Rilett	62
	(2377)			110		Cowburn	
54	(2381)	Penwick	86	111		Glasgow	29
55	2369	Roanoke	44	112	(2136)	Stuarts Draft	42

MAP SHOWING

CLAY LOCALITIES

IN WESTERN VIRGINIA

BY H. RIES AND R. E. SOMERS

BASE MAP OF VIRGINIA COMPILED IN 1914 IN COOPERATION
WITH THE U. S. GEOLOGICAL SURVEY

1920

SCALE
1:750,000—Approximately 1 inch = 12 milesNote: For boundaries of geologic formations with which the clays and shales are associated
see Geologic Map of Virginia published by the Virginia Geological Survey, 1916

80°

79°

78°



41	2240	Low Moor	83		(2236)				
42	2242	Glen Wilton	84	98	2253	Glamorgan	107		
43		Covington	111	96	2352	Glamorgan	107		
	(2304)	Nace	45	97	2354	Wise	107		
44	(2306)	Daleville	46	98	2319	Wise	107		
45	2251	Hollins	48	99	2355	Appalachia	106		
46	2256	Blue Ridge Springs	47	100	2357	Hilton	91		
47		Lithia	30	101	(2318)	Pennington	73, 104		
48	2237	Pinnacle	56	102	(2360)	Rose Hill	99		
49	2238	Buchanan	56	103	2358	Pennington	104		
50		Cloverdale	56	104		North Mountain	79		
51	2309			105	2356	Norton	106		
	2254			106	(2263)	Covington	83		
52	(2253)	Webster	57	107	(2264)				
	2307			108	(2192)	Ivanhoe	49		
	2316			109	(2196)	Pennington	104		
	2375			110	2359	Fillet	62		
53	(2344)	Lignite	84	111	2379	Coburn	29		
	(2377)			112		Glasgow	42		
54	2258	Fenwick	86	113	(2136)	Stuarts Draft	51		
	(2261)				(2137)	Wytheville			
55	2369	Roscoe	44						
56		Salem	48, 112						

K E N T U C K Y

